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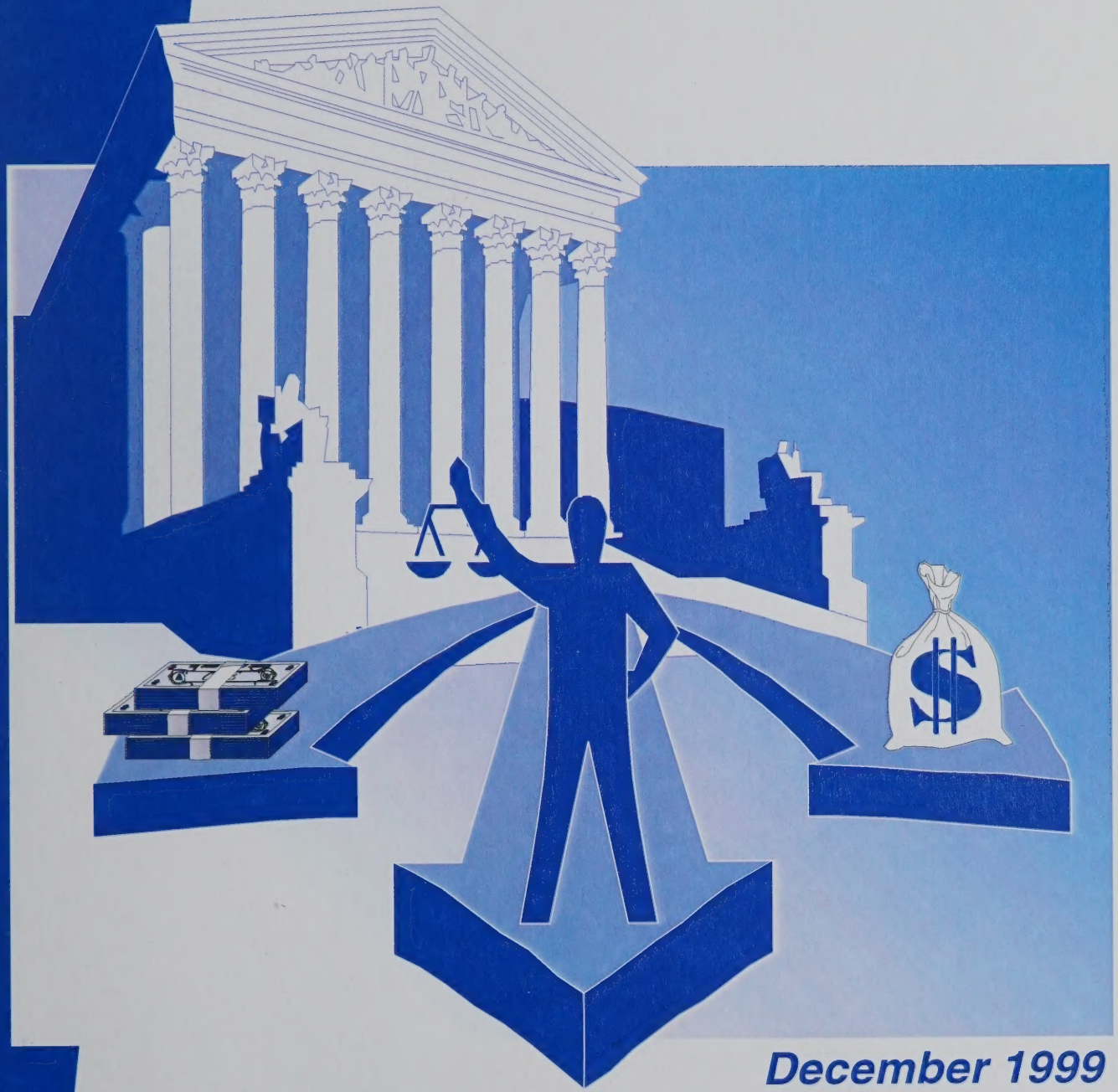
ADVANCED TECHNOLOGY PROGRAM

Capital Formation and Investment in Venture Markets: Implications for the Advanced Technology Program



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Capital Formation and Investment in Venture Markets: Implications for the Advanced Technology Program

A Report to the Advanced Technology Program and the National Bureau of Economic Research

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National Bureau of Economic Research

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U.S. DEPARTMENT OF COMMERCE
William M. Daley, Secretary

TECHNOLOGY ADMINISTRATION
Dr. Cheryl L. Shavers, Under Secretary of Technology

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Raymond G. Kammer, Director

Contents

ATP Perspective

This study was commissioned by the Advanced Technology Program (ATP) through the National Bureau of Economic Research (NBER), as part of ATP's effort in economic evaluation. The ATP's Economic Assessment Office (EAO) compiles data, conducts economic studies, and commissions studies by outside research organizations, university faculty, and consultants. These studies are multi-purpose, assessing the impact of ATP on innovative activity of private enterprises, and the effects of innovative activity on the economy. The economic processes by which R&D activities of firms lead to commercially viable innovation are complex, and the EAO therefore commissions research on special topics relating to the innovation process and the relationships between technological change and economic phenomena.[1]

The ATP is unique among federal agencies supporting research and development activities in private industry. To merit funding, an industry-initiated project proposed to ATP must focus on an enabling, high-risk technology with potential for broad economic benefits. Economists characterize these broad benefits as "spillovers," i.e., positive externalities from the innovative activity that are not fully captured by the innovating firm.

The ATP encourages companies to undertake difficult, longer term research that will lead to technologies with larger than average spillover benefits for the nation—research that the companies will not do at all, or not with the same scale, scope, or in the same time period, absent ATP support. The objectives and funding criteria of ATP differ in significant ways from that of private investors who also fund industry R&D. The ATP focuses on the public interest in new technology development, whereas private investors focus on private interests. Since ATP is a private-public cost-sharing program, for an ATP-funded R&D project to proceed, the private and public interests must overlap to some degree. The ATP therefore applies its selection criteria, which emphasize public benefit, to projects that private companies propose and to which they also commit private sector funding.

With perfect information, the ATP would be able to fulfill its mission without the chance of rejecting projects that it ought to fund, or accepting projects that it ought not to fund. But information, of course, is not perfect. To make good decisions about individual projects in the face of uncertainty, the ATP needs to learn as much as possible about what kinds of projects tend to generate large spillover benefits, and also about how to avoid funding those R&D activities that are easily and readily funded by private sector sources. Both are important to ATP's success. Other studies are addressing the analysis and measurement of spillover benefits. Here, in this study, the focus is on issues of funding.

In addition to the part of retained earnings that companies dedicate to R&D activities, U.S. companies may raise additional capital for these activities from the external capital market or from private investors. For small companies, venture capital and "angel" capital finance have increased substantially in the last decade. In 1996, Secretary of Commerce William Daley directed the ATP to foster relationships with private sector financing sources, particularly the venture capital community, and to develop a better understanding of the types of R&D activity that private sources are both willing and not willing to fund. The goal, of course, is to help ensure

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[1]Listings of ATP's evaluation studies completed and underway appear on our web site and copies may also be obtained from our office. For more about the ATP on the World Wide Web, go to http://www.atp.nist.gov; for more about ATP's evaluation program and studies completed and underway, go the above web page and select "Economic Assessment Office" and then "Publications".

that the ATP does not displace private sources of funding that are available for advanced technology development.

In support of this directive, the ATP undertook several initiatives, one being the commissioning of this study with Professors Gompers and Lerner of the Harvard Business School to examine the financing of small innovative firms by venture capitalists and "angel" investors.[2,3] The venture capital industry is important primarily for small, relatively new firms that need external sources of funding for their R&D and commercialization activities. This study by Gompers and Lerner focuses on the special problems of new high-tech firms that are highly dependent on external sources for funding of their R&D. Drawing on a number of data sources, the authors report on the patterns and trends in venture capital funding. In addition, they conducted interviews with managers at seven small start-up companies in the Boston area that had received an ATP award.

The interviews served several purposes: to identify the role played by the ATP in the R&D activities of these companies, to determine whether their needs were adequately addressed by private venture capital investors alone, and to examine the interactions between venture financing and public initiatives in assisting these firms.

In reviewing what the authors have done, the ATP finds much of value. The key findings of importance to the ATP about the trends and patterns of venture capital availability and spending are presented in Chapters 4A and 4B and are summarized as follows:

- There has been substantial growth in venture capital funds available for small high-tech start-up firms. Most of this growth is attributable to institutional investors, e.g., pension funds. The authors suggest that this shift in the source of venture capital away from the individual investor and towards the institutional investor means that there is a greater preference for less risky R&D and shorter time horizons for realizing returns on these investments.

- Lemming-like behavior on the part of many venture capitalists has led to a concentration of investments in "hot" technical areas while other areas attract little or no venture capital. The bulk of the venture capital has also tended to be geographically concentrated.

- Despite the increases in venture capital supply, only a small fraction (less than one tenth of one percent) of business start-ups annually have received venture financing in recent years.

- Venture-backed firms have tended to be more successful than their peers in making the transition from private to public ownership through initial public offerings. Also, in the five-year period after going public, venture-backed firms have been shown to be more successful than other companies. This success differential may reflect the greater control mechanisms and discipline imposed by venture capitalists as conditions of financing. This finding is consistent with ATP's strategy of encouraging the small start-up companies it funds to seek private sources of capital for additional R&D and commercialization as soon as possible.

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[2]Another current initiative of the ATP that is contributing to our understanding of what venture capitalists are, and are not, willing to fund is a study being led by the John F. Kennedy School of Government, Harvard University, titled "Managing Technical Risk: Decision-Making on Early Stage, High Risk Research." With participation by technologists, academics, business executives, financiers, and ATP officials, this effort is expected to cover the different perspectives of those who do research, make technology decisions, and risk their money.

[3]Another newly commissioned study is investigating the role of ATP funding in large-company R&D portfolios.

The seven case studies and the authors' insights from the cases are presented in Chapters 3A and 3B. From ATP's perspective, the key findings from the seven case studies may be summarized as follows:

- Each of the seven companies struggled to obtain funding to undertake its innovative research and was unable to secure sufficient funding from private sources.

- The ATP substantially expanded and enhanced the R&D activities of the seven small companies in the study.

- The companies experienced unexpected developments and changing conditions which affected both their ATP projects and, in some cases, the viability of the firms at large.

- Of the seven companies, most were very seriously oriented to the marketplace and towards commercializing the results of their technologies, but in one case there may be an appearance of a "contract research" mentality with less interest in commercialization.

- One of the companies received a second ATP award while it was experiencing serious financial and legal difficulties, suggesting that insufficient attention may have been given by the ATP to current conditions within the company at the time the second award was made.

- Several of the companies wanted more freedom in their use of ATP funds than the program was willing or able to allow given statutory restrictions, for example, to use funds to pursue commercialization.

On the basis of the seven case studies, the authors, in the Chapter 5, make five recommendations for operational improvements to the ATP. The ATP agrees in principle with three of the recommendations, but also takes issue with at least portions of four of the recommendations in consideration of ATP's legislated mission and goals. (For specifics, see the "ATP Comment" at the end of the report.)

In summary, the Gompers/Lerner report sheds valuable light on the current state of financing of small entrepreneurial firms, particularly those operating in the high-technology arena. It furthers ATP's effort to advance its understanding of the venture capital community. We welcome your comments on this and other research we have sponsored.

Rosalie T. Ruegg
Director, Economic Assessment Office
Advanced Technology Program

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Chapter 1

Motivation and Overview

Motivation (1): Why Study Subsidies to Small High-Technology Firms?

The federal government has played an active role in financing new firms, particularly in high-technology industries, since the Soviet Union's launch of the Sputnik satellite. In recent years, European and Asian nations and many U.S. states have adopted similar initiatives. While these programs' precise structures have differed, the efforts have been predicated on two shared assumptions: (1) that the private sector provides inadequate capital to new firms, and (2) that the government can identify firms for which investments will ultimately yield high social and/or private returns.

These claims have, however, received little scrutiny by economists. This is an important omission for two reasons. First, public programs to subsidize small high-technology firms have represented a significant, but little studied area of public expenditures. Tables 1.1 and 1.2, found at the end of this chapter, list these programs in the United States and overseas. These efforts are significant in magnitude. For instance, in the United States, the Small Business Investment Company program led to the provision of more than $3 billion to small firms between 1958 and 1969, more than three times the total private venture capital investment during these years (Noone and Rubel [1970]). In 1995, the sum of the financing provided through and guaranteed by the programs listed in Table 1 was at least $2.4 billion, compared to the $3.9 billion disbursed by traditional venture capital funds in that year. In 1995, the Small Business Innovation Research program provided almost $900 million to young technology-intensive firms. This was about equal to the annual rate of early-stage investments by venture capitalists in recent years (VentureOne [1996], U.S. Small Business Administration [1996]). The Advanced Technology Program has also been a significant source: of the nearly one billion dollars awarded from 1990 to 1997, fully 36% went to small businesses and an additional 10% has gone to joint ventures led by small businesses.

Second, a number of these programs are reputed to have had a positive and significant impact on economic growth. Some of America's most dynamic technology companies received support through federal programs while still private entities, including Apple Computer, Chiron, Compaq, Federal Express, and Intel. In addition to funding firms, during the 1960s publicly sponsored funding initiatives provided early experience for many of the individuals who later went on to lead independent venture organizations. Overseas, much of the recent growth of high-technology firms in such nations as Israel, Singapore, and Taiwan has been attributed to government venture capital initiatives (see OECD [1996]).

This project examines these two claims. We seek to understand the adequacy of private sector financing of young entrepreneurial firms, as well as the ability of public programs to supplement private funding. Rather than considering the whole range of financial alternatives available to small high-technology firms, we focus on one financial intermediary: the venture capital organization.

Motivation (2): Why Study the Role of Venture Capital Organizations?

The reasons for focusing on venture capital organizations are three-fold. First, venture capital represents the single largest source of private sector financing for early-stage, high-technology firms. While evidence regarding the financing of these firms is imprecise, Freear and Wetzel's

[1990] survey suggests that venture capital accounts for about two-thirds of the external equity financing raised by privately held technology-intensive businesses from private-sector sources. A more recent study of high-technology initial public offerings by Fenn, Liang, and Prowse [1997] largely corroborates this survey evidence.

Second, venture capitalists have developed unique methods for addressing the types of financing challenges that are posed by small high-technology firms. Venture capitalists take an equity stake in the firms they finance, sharing in both upside and downside risks. They undertake extensive due diligence prior to investing and provide intensive monitoring afterwards to resolve informational asymmetries. Most firms that receive venture capital financing are unlikely candidates for alternative sources of funding. They have few tangible assets to pledge as collateral and produce operating losses for many years.

Finally, the relationship between the Advanced Technology Program and the independent venture capital has been identified as a particularly critical issue. The Secretary of Commerce's July 1997 report, *Strengthening the Commerce Department's Advanced Technology Program: An Action Plan* [1997], highlighted this as one of six key areas for program improvement. Through a better understanding of this sector, the broad goals outlined in the *Action Plan* can be more effectively achieved.

Overview

We proceed in two parts. In the first half of the project, we examine the primary source of equity financing for small high-technology firms in the United States: venture capital organizations. Through two large-sample research studies, we seek to understand the ways in which the venture industry does and does not address the needs of entrepreneurial firms. We highlight the key strengths and limitations of venture capital as a financing mechanism.

The two large-sample research papers, "What Drives Venture Capital Fundraising?" and "Money Chasing Deals?," examine the macro- and micro-economic factors that have significantly influenced venture capital activity in the past few decades. The results of the first research paper reveal that U.S. regulatory and policy decisions do impact the supply of venture capital. We find that, while changes in government regulatory policies have increased the supply of available venture capital to some extent, regulatory and policy decisions have primarily affected the *demand* for venture capital. Most importantly, decreases in the capital gains tax rate, which expand the pool of individuals willing to pursue entrepreneurial careers, are associated with an increase in capital commitments to venture activities. (Regulations governing pension fund investments, such as the Department of Labor's 1979 clarification of pension policy, have boosted the supply of venture capital, but public policy shifts have primarily affected the demand for venture capital rather the supply of funds directly.) This evidence raises questions about the effectiveness of public efforts to directly supply capital to small firms.

The results of the second large-sample research paper show that the venture capital activity of the private sector has been concentrated within a few narrow areas. Specifically, an increase of capital inflow into a limited set of funds has led to an increase in the valuation of these funds' investments. Moreover, the bulk of the capital inflow has been geographically localized to regions noted for their highly valued industries. Similarly, we also found that much of the money for venture capital was being "herded" into the same "hot," expanding areas of research such as the biomedical and computer-related industries. We tentatively suggest that the ATP may be able to direct funds to industries with a potentially high social return that have received little private venture funding. While much of this discussion draws upon the two academic studies funded by

the Advanced Technology Program (available on request from the authors), we also rely upon our earlier work (collected in Gompers and Lerner [1999]).

The second half of the project focuses on the effective implementation of public programs. In particular, we ask how the public sector can interact with the venture community and other providers of capital to entrepreneurial firms in order to most effectively advance the innovation process. Rather than analyzing these challenging questions through a large-sample analysis, we rely on seven case studies. In addition to presenting the individual case studies in Chapter 3A, we present an overview of patterns and policy implications derived from the case studies in Chapter 3B.

Table 1.1. U.S. Public Venture Capital Initiatives, 1958-1997. The table summarizes programs sponsored by state and federal organizations in which equity investments or equity-like grants were made into privately held companies, or into funds that made such investments. If a program had multiple names, we report the name as of May 1997. If a program was terminated prior to this date, we record its name at the time of the termination. If an organization sponsoring a program changed its name, or if responsibility for the program was transferred between organizations, we record the name of the sponsoring organization as of May 1997. If the program was terminated prior to this date, we record the sponsoring organization at the time of the program's termination. The sources are Eisinger [1988], Lerner [1999], Organisation for Economic Co-operation and Development [1996], U.S. Small Business Administration [1994], and various news stories in the LEXIS/NEXIS database and government reports.

Sponsoring Organization	*Program Name*	*Brief Description*	*Span*
Small Business Administration	Small Business Investment Company Program	Provides capital to federally sponsored funds that make debt and equity investments in growth firms.	1958-1997
Department of Commerce	State Technical Services Program	Supported various government programs to help high-technology companies (especially new firms).	1965-1969
Department of Housing and Urban Development Model Cities Administration	Venture Capital Development Assistance	Demonstration projects in selected cities financed businesses begun by residents of targeted neighborhoods.	1967-1971
At least 30 states	At least 43 state venture funds or SBIC programs	Make investments into funds supporting new enterprises, which often focus on high-technology firms.	1970-1997
Department of State Agency for International Development	At least 13 developing country venture funds	Provided loans to financial intermediaries that made equity and debt investments in new enterprises in over 30 countries.	1971-1993
Small Business Administration	Specialized Small Business Investment Company Program	Provides capital to federally sponsored funds that make debt and equity investments in growth firms owned by disadvantaged individuals.	1972-1997
Department of Commerce National Bureau of Standards	Experimental Technology Incentives Program	Catalyzed new public programs across agencies to encourage industrial research and venture capital.	1972-1979
National Science Foundation	Federal Laboratories Validation Assistance Experiment	Funded assessments by national laboratory personnel of prototype products and processes developed by entrepreneurs.	1972-1975
National Science Foundation and Small Business Administration	Innovation Centers Experiment	Provided assistance to high-tech entrepreneurs through incubation centers, subsidies, and technical assistance.	1973-1981
Department of Energy Office of Energy-Related Inventions	Energy Related Inventions Program	Provides financing to individual inventors and small firms to commercialize energy-conserving discoveries.	1975-1997
Small Business Administration	Small Business Development Centers Program	Funds university-based centers to assist small businesses and encourage technology transfer.	1976-1997
Department of Commerce	Corporations for Innovation Development Initiative	Designed to fund state and regional corporations to provide equity financing to new firms. Only one such corporation was funded.	1979-1981
Department of Commerce Minority Business Development Agency	Technology Commercialization Program	Financed minority technology-oriented entrepreneurs, as well as centers to assist such entrepreneurs.	1979-1982
At least 15 states	At least 107 business incubators	Provide office and manufacturing space, support services, and often financing to start-up businesses.	1980-1996
11 federal agencies	Small Business Innovation Research Program	Provides awards to small technology-oriented businesses. (Also predecessor programs at 3 agencies, 1977-1982.)	1982-1997

Table 1.1 (cont'd.). U.S. Public Venture Capital Initiatives, 1958-1997.

Department of Energy Office of Energy Research	At least 6 contractor-organized venture funds	Make equity investments in spin-offs from national laboratories. (Funds organized by prime or sub-contractors at laboratories with Department's encouragement.)	1985-1997
At least 30 states	State Small Business Innovation Research Programs	Makes SBIR-like grants, often in conjunction with federal SBIR awards.	1987-1997
Department of Commerce National Institute of Standards and Technology	Advanced Technology Program	Awards grants to develop targeted technologies to firms and consortia. Some emphasis on small businesses.	1988-1997
Department of Defense Defense Advanced Research Projects Agency	Experimental venture capital investment program	Designed to make investments in private high-technology firms in exchange for equity or royalties. Program only made one investment.	1989-1991
Department of State Agency for International Development	Enterprise Fund Program	Oversees 12 federally funded venture funds investing in Eastern Europe, the former Soviet Union, and Africa.	1990-1997
Overseas Private Investment Corporation	Venture capital fund guarantees	Guarantees full or partial return of capital to investors in at least 16 private venture funds in developing countries.	1990-1997
Department of Housing and Urban Development Community Relations & Involvement Office	Tenant Opportunity Program	Funds new businesses and other initiatives by public housing residents (other aspects of program had begun in 1987).	1993-1997
Department of Energy Office of the Undersecretary	Defense Programs Small Business Initiative	Provides funding, technological assistance, and national laboratory access to small high-technology businesses.	1993-1997
11 federal agencies	Small Business Technology Transfer Program	Finances cooperative research projects between small high-technology firms and non-profit research institutions.	1994-1997
Department of Defense Cooperative Threat Reduction Program	Defense Enterprise Fund	Finances an independent venture fund investing in defense conversion projects in the former Soviet Union.	1994-1997
Department of the Treasury	Community Development Financial Institutions Fund	Invests in and provides assistance to community development venture capital and loan funds.	1995-1997
Department of Defense	"Fast Track" Program	Provides 4:1 matching funds for private financing raised by SBIR awardees.	1995-1997
Department of Agriculture Rural Business and Cooperative Development Service	Intermediary Relending Program (as amended)	Permits program managers to guarantee returns of investors in rural venture funds.	1997

Table 1.2. Overseas Public Initiatives to Encourage Venture Capital Funds Active Between 1990 and 1997. Government programs that make direct investments in firms with no private sector involvement are excluded, as are non-financial efforts (e.g., business incubators). Similarly, initiatives not directly targeting venture capital, such as general capital gain tax cuts and pension policy reforms, are excluded. Purely state- and local-level programs are also not included in the compilation. The sources are Lerner [1999], Organisation for Economic Co-operation and Development [1996], and assorted news articles and Web pages.

Country	*Program Name*	*Year*	*Brief Description*
Australia	Australia Technology Group	1993--	Public capital for independently managed venture fund.
	Management and Investment Companies Programme	1984-1991	Tax subsidies for small independently managed venture funds.
	Pooled Development Funds Programme	1992--	Tax subsidies for small independently managed venture funds.
	Small Business Innovation Fund	1997--	2:1 matching for investments by independent venture funds
Belgium	Investment Company for Flanders (GMIV)	1980--	Public capital for independently managed venture fund.
Canada	Atlantic Investment Fund	1997--	Public capital for independently managed venture fund.
	Federal Business Development Bank	1996--	Public capital for independently managed venture funds.
	Labour-Sponsored Venture Capital Corporations	1983--	Tax subsidies for quasi-public venture funds.
Denmark	Business Development Finance (VoekstFonden) Program	1995--	Subsidization of 50% of losses from approved venture capital investments.
European Bank for Reconstruction and Development	Venture Capital Initiative	1992	Public capital for independently managed venture funds in Eastern Europe and former Soviet Union.
European Community	European Community Investment Partners	1987	Public capital for independently managed venture funds in developing countries.
	European Investment Fund	1992--	Public capital to specialized intermediaries for investment in small businesses.
	European Regional Development Fund	1994--	Public capital for independently managed venture funds.
	EuroTech Capital	1988--	Maintenance of information network on cross-border venture financing opportunities. and selective investments.
	Seed Capital Programme	1988--	Subsidization of European funds making early-stage investments.
	Venture Capital Consort Scheme	1986-1993	Subsidization of loans to venture syndicates from several European nations.

Table 1.2 (cont'd). Overseas Public Initiatives to Encourage Venture Capital Funds Active Between 1990 and 1997.

Finland	Finnish Guarantee Board (FGB)	1994--	Subsidization of 50% of losses from approved venture capital investments.
	Finnish Industry Investment (STO)	1994--	Public capital for independently managed venture funds.
	Finnish National Fund for Research and Development (SITRA)	mid-1980s—	Public capital for independently managed venture funds.
	Start Fund of Kera Oy (SFK)	mid-1980s—	Public capital for independently managed venture fund.
France	Societe Francaise de Guarantie des Financements des Petites et Moyennes Enterprises (SOFARIS)	1982--	Public guarantee of 70% of losses from venture investments in young firms.
Germany	Beteiligungskapital fuer Junge Technologieunternehmen (BJTU)	1989-1995	Co-investments with venture funds, in return for limited return.
	Beteiligungskapital fuer Kleine Technologieunternehmen (BTU)	1995--	Co-investments with venture funds, in return for limited return.
	Deutsche Gesellschaft fuer Wagniskapital (WFG)	1975--	Public guarantee of 75% of losses of independent venture fund.
	Kreditabstaldt fuer Wiederaufbau (KfW) Venture Capital Loan Guarantees	1989-1994	Interest-free loans to venture capitalists that allowed them to partially exit their investments.
	Unternehmensbeteilungsgesellschaften (UBGs)	1987--	Tax subsidies for independently managed venture funds.
India	Technology Development and Information Company of India (TDICI)	1986--	Public capital for independently managed venture funds.
	Capital Gains Tax Incentives	1995--	Tax subsidies for independently managed venture funds.
Ireland	Forbairt Agency Co-Investment Fund	1994--	Co-investment with venture funds, in return for limited return.
Israel	Inbal	1991--	Public guarantee of 80% of losses of publicly traded venture funds.
	Yozma Venture Capital	1991--	Provision of up to 40% of capital to venture funds, in return for a limited return.
Japan	All-Japan Venture Development Funds	1995--	Public capital for quasi-public regional venture funds.
	Small Business Investment Company Program	1962--	Public capital for loan guarantees to federally sponsored venture funds.
	Japan Development Bank New Business Investment Co.	1996--	Public capital for independently managed venture funds.
Malaysia	Malaysian Technology Development Corp.	1992--	Public capital for independently managed venture funds.

Table 1.2 (cont'd). Overseas Public Initiatives to Encourage Venture Capital Funds Active Between 1990 and 1997.

Netherlands	Private Participation Guarantee Order Scheme (PPM)	1981-1995	Public guarantee of 50% of losses from approved venture investments.
Singapore	Economic Development Board	1994--	Public capital for independently managed venture funds.
	Regional Investment Corporation		
	INTECH	1985--	Subsidies for training of new venture capitalists.
	National Science & Technology Board	1995--	Public capital for independently managed venture funds.
	Technology Development Funds		
	Pioneer Service Incentive	1985--	Government subsidies of independent venture capital funds.
	Section 13H Tax Incentive	1985--	Tax subsidies for independently managed venture funds.
Sweden	Alte and Bure funds	1992--	Public capital for publicly traded funds that invest in other venture funds.
Taiwan	Capital Gains Tax Incentives	1987--	Tax subsidies for independently managed venture funds.
United Kingdom	British Technology Group	1982-1992	Public capital for independently managed early-stage venture funds.
	Venture Capital Trust Scheme	1995--	Tax subsidies for publicly traded independent venture funds.
World Bank	International Finance Corporation	1970s—	Public capital for independent venture funds in developing countries.

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Chapter 2

Venture Capital and the Financing of Small High-Technology Firms

Introduction

The recent economic literature suggests several reasons for concern about the adequacy of private sector mechanisms to finance small high-technology firms. A growing body of empirical research on capital constraints (reviewed in Hubbard [1998]) documents that an inability to obtain external financing limits many forms of business investment. Particularly relevant are works by Hall [1992], Hao and Jaffe [1993], and Himmelberg and Petersen [1994]. These show that capital constraints appear to limit research-and-development expenditures, especially in smaller firms. A related body of literature documents that investments in R&D yield high private and social rates of return (e.g., Griliches [1986], Mansfield, *et al.* [1977]). These findings similarly suggest that a higher level of R&D spending would be desirable.

Why are Investments in Entrepreneurial Firms Problematic?

Entrepreneurial firms often develop products and ideas that require substantial capital during the formative stages of the company's life. Many entrepreneurs do not have sufficient funds to finance projects themselves, and they must therefore seek outside financing. But because of the nature of the entrepreneurial setting, the financing process can often be a troubled one.

To briefly review the types of conflicts that can emerge in these settings, Jensen and Meckling [1976] demonstrate that agency conflicts between managers and investors can affect the willingness of both debt and equity providers to invest capital. If the firm raises equity from outside investors, the manager has an incentive to engage in wasteful expenditures (e.g., lavish offices) because he may benefit disproportionately from these but does not bear their entire cost. Similarly, if the firm raises debt, the manager may increase risk to undesirable levels. Because providers of capital recognize these problems, outside investors demand a higher rate of return than would be the case if the funds were internally generated.

Even if the manager is motivated to maximize shareholder value, informational asymmetries may make raising external capital more expensive or even preclude it entirely. Myers and Majluf [1984] and Greenwald, Stiglitz, and Weiss [1984] demonstrate that equity offerings of firms may be associated with a "lemons" problem. If the manager is better informed about the firm's investment opportunities and acts in the interest of current shareholders, then he only issues new shares when the company's stock is overvalued. Indeed, numerous studies have documented that stock prices decline upon the announcement of equity issues largely because of the negative signal that it sends to the market.

These information problems have also been shown to exist in debt markets. Stiglitz and Weiss [1981] show that if banks find it difficult to discriminate among companies, raising interest rates can have perverse selection effects. In particular, high interest rates discourage all but the highest-risk borrowers, so the quality of the loan pool declines markedly. To address this problem, banks may restrict the amount of lending rather than increasing interest rates.

These problems in the debt and equity markets are a consequence of the information gaps between the entrepreneurs and investors. If the information asymmetries could be eliminated, financing constraints would disappear. Financial economists argue that venture capital organizations can address these problems. By intensively scrutinizing firms before providing

capital and then monitoring them afterwards, they can alleviate some of the information gaps and reduce capital constraints.

How Do Venture Capitalists Address These Problems?

A series of academic studies have documented the mechanisms that venture capitalists employ to address these challenges. We will highlight six of these responses below. Gompers [1995, 1997], Lerner [1994, 1995], and Sahlman [1990] are empirical examples; see Barry [1994] for an overview of the extensive theoretical literature Gompers [1995, 1997], Lerner [1994, 1995], and Sahlman [1990] are empirical examples; see Barry [1994] for an overview of the extensive theoretical literature

The first set relates to the financing of firms. First, *from whom* a firm acquires capital is not always obvious. Each source—private equity investors, corporations, and the public markets—may be appropriate for a firm at different points in its life. Furthermore, as the firm changes over time, the appropriate source of financing may change. Because the firm may be very different in the future, investors and entrepreneurs need to be able to anticipate change.

Second, the *form* of financing plays a critical role in reducing potential conflicts. Financing provided by private equity investors can be simple debt or equity, or it can involve hybrid securities like convertible preferred equity or convertible debt. These financial structures may screen out overconfident or underqualified entrepreneurs. The structure and timing of financing can also reduce the impact of uncertainty on future returns.

A third element is the *division* of the profits between the entrepreneurs and the investors. The most obvious aspect is the pricing of the investment: for a given cash infusion, how much of the company does the private equity investor receive? Compensation contracts can be written to align the incentives of managers and investors. Incentive compensation can be in the form of cash, stock, or options. Performance can be tied to several measures and compared to various benchmarks. Carefully designed incentive schemes can avert destructive behavior.

The second set of activities of private equity investors relates to the strategic control of the firm. *Monitoring* is a critical role. Both parties must ensure that proper actions are taken and that appropriate progress is being made. Critical control mechanisms—e.g., active and qualified boards of directors, the right to approve important decisions, and the ability to fire and recruit key managers—need to be effectively allocated in any relationship between an entrepreneur and investors.

Venture capital investors can also encourage firms to *alter the nature of their assets* and thus obtain greater financial flexibility. Patents, trademarks, and copyrights are all mechanisms to protect firm assets. Understanding the advantages and limitations of various forms of intellectual property protection and coordinating financial and intellectual property strategies are essential to ensuring a young firm's growth. Investors can also shape firms' assets by encouraging certain strategic decisions, such as the creation of a set of "locked-in" users who rely on the firm's products.

Evaluation is the final, and perhaps most critical, element of the relationship between entrepreneurs and private equity investors. The ultimate control mechanism exercised by the private equity investors is to refuse to provide more financing to a firm. In many cases, the investor can—through direct or indirect actions—even block the firm's ability to raise capital from other sources.

The importance of these mechanisms is underscored by the success of venture-backed firms. A variety of evidence suggests that venture-backed firms are more successful than their peers:

- One illustration of this difference is in the share of the companies making the transition from private to public ownership through initial public offerings (IPOs), which typically include many of the most successful firms. In recent years, fully 30% of the IPOs have been of venture-backed firms. (Detailed summary statistics are available in Gompers and Lerner [1997].) This is much greater than the share of young firms receiving venture financing.[4]

- Venture-backed firms are also more successful after going public. Brav and Gompers [1997] show that in the five years after going public, IPOs that had previously received equity financing from venture capitalists outperform other offerings.

- Venture capital appears to contribute to technological innovation. In a panel study of twenty industries over three decades, Kortum and Lerner [1998] demonstrate a relationship between the extent of venture financing in particular industries and their rate of patents. The pattern appears to be robust to a variety of controls for reverse causality and alternative explanations.

What Are the Limitations of Venture Capital Investment?

At the same time, venture capital appears to have important limitations as a source of financing for small high-technology firms. Both the unevenness of the inflows into venture funds and the concentration of investments within a few narrow technologies may limit its effectiveness as a source of financing. The two large-sample empirical papers funded as part of this analysis, found in Chapter 4, discuss these limitations. In this section we highlight some of the reasons why independent venture capital funds may not be sufficient to fund all promising small high-technology firms.

The first of these limitations relates to the supply of venture capital. During the past twenty years, commitments to the U.S. venture capital industry have grown dramatically. This growth has not been uniform: peaks in fundraising have been followed by major retrenchments. Despite the importance of and interest in the venture capital sector, the underlying causes of these dramatic movements in venture fundraising are little understood.

In the paper, "What Drives Venture Capital Fundraising?" (which is Chapter 4A of this report), we analyze these patterns systematically. We find that regulatory changes have had an important impact on commitments to venture capital funds. The Department of Labor's 1978 clarification of the prudent man rule, which enabled pension funds to freely invest in venture capital, had a generally positive effect on commitments to the industry, as it increased the supply of funding.

Capital gains tax rates also appear to have an important effect on fundraising at both the industry and venture organization level. Decreases in the capital gains tax rates are associated with greater venture capital commitments. Rate changes, however, affect taxable and tax-exempt investors almost identically. Decreases in capital gains tax rates appear to increase commitments to venture capital funds not through increases in the desire for contributions to new funds by taxable investors, but rather through increases in the demand for venture capital investments when workers have greater incentives to become entrepreneurs.

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[4]In 1996, a record year for venture disbursements, 628 companies received venture financing for the first time (VentureOne [1997]). By way of comparison, the Small Business Administration [1996] estimates that in recent years close to one million businesses have been started annually.

A key point to emerge from this analysis is the importance of economic policies in shaping the supply of venture capital. These shifts are largely exogenous to the nature of technological opportunities. This pattern suggests that it is by no means clear that the optimal number of small high-technology firms are receiving financing from the venture sector or that there is no role for public venture capital programs. There is the possibility, however, that the level of venture capital funding may be too high. Furthermore, if public policy can more readily affect the demand for venture capital than the supply of funding, then it is unclear whether direct grant programs such as the ATP can affect fundraising levels. The optimal level of venture capital funding and the manner in which it can be affected by the ATP program remain open research questions.

The paper, "Money Chasing Deals?" (Chapter 4B of this report), examines the narrow focus of venture capital investment. Venture capital investments are tremendously concentrated, whether measured by the technological span of the firms backed, the location of the firms, or the size of the investment. One of the key implications of "Money Chasing Deals?" is the potentially detrimental impact that this concentration can have.

Panels B and C of Table 2.1, found at the end of this chapter, document this pattern, showing the distribution of early-stage venture financings by state and Standard Industrial Classification (SIC) code in 1995. The concentration of awards in California and Massachusetts, as well as in computer software and communications sectors, is apparent.

This concentration may be problematic, whether we examine its impact on social or private returns. On the one hand, several models argue that institutional investors frequently engage in "herding": making investments that are too similar to one another. These models suggest that a variety of factors—for instance, assessing performance on a relative, not an absolute, basis—can lead to investors obtaining poor performance by making too similar investments. (Much of the theoretical literature is reviewed in Devenow and Welch [1996]; Sahlman and Stevenson [1986] present a case study suggesting such behavior by venture capitalists.) As a result, social welfare may suffer because value-creating investments in less popular technological and geographic areas may have been ignored.

The concentration in technological investment areas may be a matter of particular concern. An extensive literature on technology races (reviewed in Reinganum [1989]) shows how a small initial technological advantage can translate into a sustained lead. If venture capital organizations neglect making small investments into a wide variety of technologies, the long-run detrimental impact on America's competitive position may be substantial.

"Money Chasing Deals?" examines the pattern of investment during the most recent period of growth (between 1987 and 1995). As venture fundraising climbed, investments remained narrowly concentrated on healthcare and information technologies. Rather than diversifying their investments, venture groups bid up the price paid for individual investments.

We employ a dataset of over four thousand venture investments made between 1987 and 1995 as well as detailed information on capital inflows. Because gaps of one to two years between refinancings of venture-backed firms are typical, a price index based purely on the changes in valuations between financings for the a given company would be incomplete and misleading. We consequently employ a hedonic approach, regressing the valuation of firms on characteristics such as age, stage of development, and industry, as well as inflow of funds into the venture capital industry. We also control for public market valuations through indexes of public market prices of firms in the same industries and average book-to-market and earnings-to-price ratios.

In this way, we seek to disaggregate whether movements in valuations reflect the flow of funds into the private equity industry or alternatively the changing composition of transactions or shifts in public market values. We find a strong relation between the valuation of venture capital investments and capital inflows. While other variables also have significant explanatory power—for instance, the marginal impact of a doubling in public market values was between a 15% and 35% increase in the valuation of private equity transactions—the inflows variable is significantly positive. A doubling of inflows into venture funds led to between a 7% and 21% increase in valuation levels. The results are robust to the use of a variety of specifications and control variables. These results corroborate practitioner claims that increasing capital inflows have led to higher security prices, or colloquially, "too much money chasing too few deals." (Three representative accounts over the decades are Noone and Rubel [1970], Sahlman and Stevenson [1986], and Asset Alternatives [1996].)

We also find that firms located in geographical areas where venture capitalists tend to concentrate and in industries that are particularly sought after increase in price even more in response to venture inflows. This suggests that attractive, underfunded opportunities exist in overlooked areas and technologies.

It is also worth noting that there is another way in which venture capital investments are concentrated: the similarities in investment size. In particular, venture funds tend to make quite substantial investments, even in young firms. For instance, the mean venture investment in a start-up or early-stage business between 1961 and 1992 was $1.8 million (in 1992 dollars) (Gompers [1995]).

The substantial size of these investments is largely a consequence of the demands of institutional investors. The typical venture organization raises a fund (structured as a limited partnership) every few years. Because investments in partnerships are often time-consuming to negotiate and monitor, institutions prefer making relatively large investments in venture funds (typically $10 million or more). Furthermore, governance and regulatory considerations lead investors to limit the share of a fund that any one limited partner holds. (The structure of venture partnerships is discussed at length in Gompers and Lerner [1996, 1999].) These pressures lead venture organizations to raise substantial funds. As the venture industry has grown, the average fund size has increased, from $30 million in 1985 to $80 million in 1995 (VentureOne [1996]). Because each firm in a portfolio must be closely scrutinized, the typical venture capitalist is responsible for no more than a dozen investments. Venture organizations are consequently unwilling to invest in very young firms that only require small capital infusions. Panel A of Table 2.1 compares seed and early-stage investments by venture funds with the total amount raised by these funds.[5]

Are Alternative Financing Sources Adequate?

It may be wondered why these inefficiencies in the venture capital market should be a source of general concern, much less public intervention. A natural question is why entrepreneurial firms

[5]There are two primary reasons why venture funds do not simply hire more partners if they raise additional capital. First, the supply of venture capitalists is quite inelastic. The effective oversight of young companies requires highly specialized skills that can only be developed with years of experience. A second important factor is the economics of venture partnerships. The typical venture fund receives a substantial share of its compensation from the annual fee, which is typically between 2% and 3% of the capital under management. This motivates venture organizations to increase the capital that each partner manages. Recently several industry leaders have explored mechanisms to facilitate investments by institutions in very small venture funds. These partnerships, they hoped, could readily make small investments in start-up firms. These efforts have encountered considerable difficulties (see Vincenti [1996]).

do not rely on the several alternative capital sources that also finance entrepreneurial firms. Can small high-technology firms raise capital from other financing sources, most notably individual investors or banks?

Both of the leading alternative sources of financing for entrepreneurial firms, however, have substantial limitations. These limitations are particularly critical in those small high-technology industries that are particularly interesting to policy-makers.

The informal risk capital market consists of individuals commonly referred to as "angels." These "angels" are wealthy businessmen, doctors, lawyers, and others who are willing to take an equity stake in a fledgling company in return for seed capital. Firms that require substantial amounts of money, however, may not be able to receive sufficient capital from the "angel" network because the market is dispersed with little information sharing and the amount of invested capital tends to be small. The amount that a firm can raise from individual investors is usually much less than the minimum financing round that a venture fund will consider providing. Freear and Wetzel [1990] report that the median financing round raised by private high-technology firms from individual investors was about $200,000. 82% of the rounds from individuals were under $500,000.

Similarly, bank financing is unlikely to fill the gap for technology-based firms. Companies that lack substantial tangible assets and have very uncertain prospects are unlikely to receive substantial bank loans. These firms face many years of negative earnings and are unable to make interest payments on debt obligations. This characterization applies to many, if not most, technology-based young firms.

Thus, a substantial gap exists between the resources that firms can raise from individual investors and from venture capitalists. Bank loans may also not be able to address this problem. Awards from programs such as the Advanced Technology Program may partially fill these gaps, as well as addressing the concerns about the geographic and industry concentration of awards discussed above.

What Are Implications for the Advanced Technology Program?

These analyses have two primary implications for the administrators of the Advanced Technology Program.[6] In this final section, we highlight these implications for program management. These should be viewed alongside the recommendations from the case studies summarized in Chapter 3B.

First, we suggest that ATP administrators should be sensitive to the importance of the venture capital sector as a source of financing. In many cases, funds from the Advanced Technology Program cannot carry the technology all the way to the marketplace. At some point, additional resources will be required. Furthermore, as discussed above, venture capitalists provide a range of services in addition to their capital. These may be difficult to duplicate through other means. Thus, venture capital is an important—and in many instances, the best—financing source as high-technology firms move new products or services from conception to the market.

Second, we suggest the need to tailor the Advanced Technology Program's awards to reflect the dynamics of the venture capital market. This awareness is likely to lead to opportunities to maximize the return from public funds. One example is the industry concentration of venture

[6]See Lerner [1999] for a detailed discussion of similar issues in the context of another Federal technology program.

funds discussed above. It probably makes little sense to target awards in technologies that have recently attracted heavy backing from venture investors, such as human genomics or Internet tools. Public funding in areas with extensive private financing may lead to a "crowding out" phenomenon: public funds may replace private expenditures for research. The total amount spent on R&D and resulting innovation may consequently not increase much in these cases (for a discussion of this problem, see Wallsten [1997]). Rather, it seems more sensible to target the broad array of technologies not attracting much interest from the venture community.

Similarly, it may make sense to adjust the Program's strategy during periods when venture investors are experiencing difficulties raising new funds (e.g., much of the 1970s, the late 1980s, and the early 1990s). A critical mechanism in the venture capitalist's tool-kit is the staging of investments. Giving entrepreneurs only part of the money they need and tying the possibility of refinancing to reaching a particular technological milestone helps limit venture capitalists' losses by allowing the venture capitalist to cut off funding to underperforming firms. (By way of contrast, established corporations, which usually lack such disciplinary mechanisms, have been known to spend hundreds of millions of dollars on new ventures before terminating them.) During sudden fundraising droughts, however, this method can lead to firms with promising technology being cut off from further funding. As our case studies indicate, Advanced Technology Program funds have, in some cases, allowed small companies with promising technologies that were experiencing technological delays to reach a stipulated milestone and obtain additional financing. This may well be an attractive strategy to pursue during these periods.

Table 2.1. Volume of Venture Capital Activity. The table provides an overview of investment activity by U.S. venture capital organizations. Panel A indicates the total amount raised by venture capital funds and the amount of early-stage investment, all expressed in 1994 dollars. No data are available on the number of early-stage investments prior to 1981. Panels B and C display the amount of venture investments in 1995, disaggregated by the leading states and industries. The sources are VentureOne [1996] and unpublished databases of Venture Economics and VentureOne.

Panel A: Amount of Venture Activity

	Venture Capital	Early-Stage Investments by Venture Funds	
Year	*Raised in Year*	*$ of Financings*	*# of Financings*
1977	91	474	
1978	442	520	
1979	503	755	
1980	1260	802	
1981	1713	806	227
1982	2061	813	343
1983	5516	1707	413
1984	4931	1689	568
1985	4240	1194	529
1986	4429	1478	716
1987	5550	1440	796
1988	3822	1272	674
1989	3858	1119	623
1990	2173	705	571
1991	1569	458	335
1992	2822	646	435
1993	3008	765	368
1994	4596	1005	499
1995	4536	1438	611

Panel B: Leading States, Venture Financing, 1995

State	*$ of Financings*	*% of Total*	*# of Financings*
California	2274	30.6	437
Massachusetts	772	10.4	131
New Jersey	724	9.7	36
Texas	352	4.7	40
Illinois	340	4.6	29

Panel C: Leading Industries, Venture Financing, 1995

Industry (SIC Code)	*$ of Financings*	*% of Total*	*# of Financings*
Communications & networking	1376	18.5	180
Software & information services	1239	16.7	291
Retailing & consumer products	1207	16.2	90
Medical compounds	716	9.6	113
Medical devices & equipment	607	8.2	108

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Chapter 3

Case Studies of ATP Awardees

Introduction

The preceding chapter has enhanced our empirical understanding of imperfections in the financial markets for entrepreneurial firms. In this chapter, we take a more qualitative approach. Through face-to-face interviews with seven ATP-funded small companies, we have attempted to identify common features—as well as unique circumstances—of each company's ATP experience.

The seven companies in our sample span such industries as biotechnology, electronics, and software development. The companies were chosen from a pool of ATP-funded companies located in the Boston area. Our objective was to select a small but diverse group of firms. We, therefore, not only chose firms from a variety of industries, but also picked companies based upon such attributes as the types of outside capital sources, the extent of commercial partnerships, the current status of ATP projects, and the number of ATP grants awarded.

From the beginning, several interviewees voiced concerns about the level of attribution that would be used in our final report to the ATP. They felt uncomfortable with providing candid critiques of the ATP, believing that such comments could impact future ATP grant proposals. In response to these concerns, we established a set of self-imposed interview guidelines. These guidelines were designed to insure candor in the interview process by preventing individual companies from having to worry about being audited or evaluated on the basis of their responses.

In accordance with these guidelines, we have divided this chapter into two distinct parts. Part A briefly examines each company on an individual basis, with special emphasis placed on the role that ATP funding has played in the company's evolution. In this section, each company was allowed to review their written profile and make editing suggestions. Part B discusses the relevant issues in a broader context—focusing on the key themes and insights, rather than on individual companies. Because quotes are not attributed and firm-specific references are not identified, this portion of the chapter was not submitted to the companies for review. Both Part A and Part B reflect the conclusions and opinions of the authors only, and neither should be constituted as an official information release from any of the seven companies included in our report.

The case studies are based on our interviews with the companies themselves and public documents. We have not reviewed the internal records of the ATP, and the cases do not represent the official views of the ATP.

A Note About Methodology

Each of the seven case studies (Aphios, BioHybrid, Continuum, Cynosure, Kopin, Kurzweil AI, and Torrent) contained in this report is divided into three sections. The first section provides a brief profile of the company's technology, market focus, major milestones, and financial history. In this section, a special emphasis is placed on factors that could affect how the company completes and later commercializes its ATP-funded research—a theme more fully explored in Part B of this chapter.

The second section of each case study discusses the company's ATP-sponsored project(s) and examines the overall impact of ATP funding. Topics explored in this section include unanticipated research challenges, eventual project outcomes, the effect on the company's research agenda, and the interplay between ATP grants and other public and private funding sources.

The third section of each case study outlines the company's current objectives and future plans, and summarizes any recent developments. (These cases were completed in the fall of 1997, and do not incorporate subsequent developments.) In general, the seven case studies feature numerous direct quotes from each of the companies on a variety of relevant issues. Our own evaluation of these comments is largely reserved for Part B.

A. Individual Case Studies

3A-1. Aphios Corporation

A Brief Company Profile

Trevor Castor founded the Aphios Corporation (formerly Bio-Eng., Inc.) in 1988 with the mission to develop enhanced biopharmaceuticals for the treatment of cancer and other infectious diseases. Prior to founding Aphios, Castor had spent most of his career as a consultant on mechanical and chemical engineering issues relevant to the oil, gas, and chemical businesses. When the oil and gas industry encountering a severe retrenchment in the wake of a fall in global oil prices in the mid-1980s, Castor decided to pursue opportunities in biotechnology—a blossoming field which, he believed, was in need of more people who understood how to cost-effectively scale up and industrialize scientific breakthroughs. Castor, who had considerable experience in such matters, thought that supercritical fluids—gases that exhibit enhanced fluid-like properties under controlled temperature and pressure—could be used to more easily and efficiently manipulate cellular structures.[7]

Looking to apply supercritical fluid techniques in a variety of ways, Castor focused Aphios' research endeavors around two distinct objectives. The first objective was to have the company's Biologics Division develop an improved method for inactivating viruses in plasma—an important step in the production of blood-derived therapeutics. Aphios' process utilizes supercritical fluids (what the company calls its proprietary "SuperFluids" technology) to permeate and inflate viral particles, then decompress and rupture them at their weakest points.[8]

Second, the company's Biopharmaceutical Division designs and manufactures naturally occurring pharmaceuticals. Rather than creating entirely new drugs, Aphios focuses its resources on developing improved versions and analogs of existing medications, most notably the anti-cancer drug Taxol. Unlike proprietary drug Taxol (produced by Bristol-Myers Squibb) which is derived from Himalayan-grown Indian yew trees, Aphios' generic version (paclitaxel) is isolated from nursery-grown ornamental yew trees. According to company literature, by combining SuperFluids techniques with this alternative source material, paclitaxel can be produced for about half the cost of its name-brand counterpart.

As for Aphios' financial history, Castor decided early on that it would be best to first demonstrate the value of the company's technology before trying to attract venture capital investors. During this three-year demonstration period, Aphios collected $150,000 in funding from a joint research agreement with a large pharmaceutical company, as well as another $500,000 in Phase I and Phase II SBIR grants from the National Science Foundation. Castor used his own funds to cover the rest of the company's expenses.

But in 1991, despite the progress that had been made during this demonstration period, Castor had come up empty-handed in his search for long-term financial support from venture capitalists or corporate sponsors. In September, Aphios nearly went bankrupt and, according to Castor, applying for an ATP

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[7]Castor had learned about supercritical fluids through his work in the petroleum industry. Supercritical fluids are also routinely used in the beverage industry to decaffeinate coffee and to extract hops.

[8]In addition to licensing the process, Aphios is looking to commercialize products (such as fibrin glue) which utilize the inactivation techniques.

grant was one of the last funding avenues available to the company. Castor drafted his ATP proposal in a matter of weeks and shortly thereafter was awarded a $2 million grant.

The ATP grant helped the company avert bankruptcy, but Aphios needed more financial backing than a steady stream of research funding would provide. Because Castor wanted to begin commercializing the technologies that the company had already developed, he hired Jim Sherblom to provide fundraising savvy and financial expertise. Sherblom had served as the Chief Financial Officer of Genzyme Corporation. More recently, he had spent four years at the helm of another biotech company, TSI Inc., before that company's board of directors replaced him.[9] In his collaboration with Castor, Sherblom was a self-proclaimed "venture catalyst." He was given the immediate task of helping Aphios attract millions of dollars in venture capital financing.

In May 1994, an industrial accident at an Aphios laboratory claimed the life of an intern from a local college, and the company's prospects for venture capital financing diminished. In response to the accident, a venture capital firm that had previously expressed interest in Aphios immediately distanced itself from the company. Litigation fears also caused Aphios' board of directors to disband. To keep Aphios afloat, Castor was eventually forced to reduce its staff of 30 to only five employees. Aphios ultimately was sued, and litigation on the matter was still pending in November 1997.

In 1995, Castor and Sherblom tried to regroup from the industrial accident by founding Orisa Pharmaceuticals, a company exclusively dedicated to the manufacture of paclitaxel. Castor and Sherblom planned to build a plant in western Michigan, but the financing never materialized. A Grand Rapids, Michigan-based investment banking firm, Cygnet Resources, Inc., was supposed to raise $12 million for Aphios, but eventually Castor terminated the relationship. Orisa Pharmaceuticals was subsequently liquidated.

In the summer of 1995, Castor also confronted the possibility of having to liquidate Aphios. The industrial accident had placed a tremendous financial and psychological burden on the company, and an infusion of capital was badly needed. As in 1991, the company applied for and received a $2 million ATP award at a critical moment. When the ATP grant was combined with additional funds generated from new collaboration efforts, liquidation fears subsided and the company stayed in business.

Aphios and the Advanced Technology Program

Since its inception, Aphios primary funding has been $8 million in government research grants, including $4 million from the ATP. Given that about 80 percent of the company's current revenues come from government grants (with another 10 percent from collaborations with other companies, and the remaining 10 percent from product sales), the ATP has been Aphios' single largest funding source.

In the company's first ATP project, Aphios built upon the research that it had already completed through the SBIR program. While the company's SBIR project had focused on using SuperFluids processes to "disrupt" troublesome microbial cells, the ATP-funded research sought to apply these techniques to the more complicated task of inactivating viruses and viral-like particles. The project was thus at the very core of Aphios' research agenda.

In the company's second ATP-funded project, however, instead of building on preexisting work, Aphios extended its research to a new area of inquiry. Because only a few thousand of the billions of microorganism species found in the ocean have been catalogued, Aphios proposed a marine

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[9]Under Sherblom's leadership, TSI's revenues had jumped to $58 million, but the company was persistently unprofitable. The company lost $32 million in 1993, and its stock price, once as high as 15, plunged to below 2. As a result, the board of directors replaced Sherblom.

microorganism discovery and saline fermentation program—a search for the vast array of potential new drugs that may reside in the depths of the ocean.[10]

Castor's project proposal was based in part on an abbreviated ATP proposal submitted in 1994 by Janice Thompson of CalBioMarine Technologies. Since the submission of that abbreviated proposal, CalBioMarine had sold many of its marine microbiology intellectual properties to Aphios—making Aphios the natural project successor. Castor hired Thompson as a consultant to the project and the research was structured as a collaborative effort. Most notable among the research partners was Bristol-Myers Squibb. The multinational healthcare company agreed to analyze marine microorganism extracts from Aphios in its advanced screening laboratories—with Aphios being paid for each "hit" that the screening process uncovered.

In addition to these two ATP-funded projects, Castor said that he submitted two additional proposals that did not end up receiving ATP support. According to Castor, one proposal (for paclitaxel manufacturing) likely failed because it was too close to the commercialization stage. The other proposal (for a new application of SuperFluids) was unsuccessful, Castor said, because he hired an outside consultant to write the business plan component.

But regardless of the proposals that did not garner ATP support, Castor emphasized that the ATP had made a substantial difference in alleviating a problematic situation that exists in the biotechnology industry. "It seemed as though to attract support from a large company like a Bristol-Myers Squibb, you had to already have an infrastructure in place," Castor said. "But you couldn't have an infrastructure in place without the support of one of these large companies. The ATP grant helped to remedy this situation." Furthermore, Castor stressed that ATP grants have provided Aphios with much-needed ballast. This stabilizing influence has helped keep the company afloat during tough times, and has been especially important for Aphios in light of the company's industrial accident and pending lawsuit—incidents which have severely handicapped Aphios' ability to attract private equity investors.

In comparing the ATP to other government grant programs, Castor highlighted the rapid turnaround time as an extremely valuable feature of the ATP's application process. Conversely, Castor emphasized that the SBIR program's staged-funding approach creates substantial inefficiencies. During the gap between Phase I and Phase II financing, for instance, entire research agendas often gather dust as the company awaits the results of the Phase II evaluation. "By the time a company finally gets funding, the entire technological cycle has changed," Castor said. "The relevant personnel have probably also changed. And during this delay, a great deal of momentum is lost."

On the Horizon

Castor's immediate objective in November 1997 is to raise $15 million for the construction of a paclitaxel manufacturing plant—with some of the necessary financing being generated from potential supplier relationships. Aphios currently produces relatively small quantities of research-grade paclitaxel, which it began selling to drug companies in 1994. But Aphios' entry into the retail Taxol market has been limited by a 1990 FDA Corporate Research and Development Award (CRADA), which granted Bristol-Myers Squibb the exclusive rights (until December 1997) to produce the drug in the $1 billion U.S. market. Soon after the award expires, Castor hopes to have the manufacturing capabilities in place to obtain a 10 percent market share.

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[10]Components of the project include acquiring a large library of microorganisms from different ocean locations and depths, developing methods to screen these libraries for commercially-promising substances, and demonstrating that saline fermentation processes can yield sufficient amounts of useful natural chemical products.

3A-2. BioHybrid Technologies, Inc.

A Brief Company Profile

Dr. William Chick, M.D., and John Hayes founded BioHybrid Technologies in 1985 with the overall objective of developing artificial internal organs for the treatment of a number of diseases. Chick had been a professor of biochemistry and medicine at the University of Massachusetts Medical School since 1981, and organized a diabetes-endocrinology research center at the university in 1983. Hayes had been a founder, principal, and treasurer of Venture Founders, an early-stage venture capital firm specializing in high-technology companies. Because of Chick's expertise in diabetes research, the company soon concentrated its efforts on developing an implantable artificial pancreas for the treatment of Type I (insulin-dependent) and Type II (non-insulin-dependent) diabetes.

To raise capital for the project, Hayes and Chick began a search for potential corporate sponsors. They wanted to steer clear of venture capital if at all possible because they felt one requirement of such financing was that owners hand over a large portion of their equity stake in the company. Hayes and Chick were able to avoid this dilution of ownership when they secured long-term financial support from W.R. Grace & Company, a major specialties chemical company with a growing interest in specialized healthcare services. In BioHybrid's agreement with W.R. Grace, the artificial pancreas project was organized as a joint program.[11] As part of the arrangement, W.R. Grace agreed to fund millions of dollars of BioHybrid's development costs. At the time, Hayes was told that the artificial pancreas project was one of the largest external R&D efforts being sponsored by W.R. Grace.

By 1991, the BioHybrid-led project had yielded a prototype. Referred to as "the hockey puck" because of its size and shape, the device was an immunoprotective membrane that surrounded living pancreatic cells. It was contained within a plastic housing that regulated insulin production according to a patient's blood glucose level. Because human pancreatic tissue was scarce, BioHybrid's strategy was to use islet cells from pig pancreata.[12]

But in early 1993, W.R. Grace delivered notice of its intent to terminate its contractual relationship with BioHybrid. The chemical company intended to take the hockey puck technology in-house to get it ready for clinical trials. Although BioHybrid would no longer receive financial support, a licensing agreement allowed the company to retain significant rights in the technology it had developed for W.R. Grace.

Without funding from W.R. Grace, BioHybrid faced a whole new set of financial challenges. BioHybrid still had its laboratory, but the more advanced technology that the company wanted to pursue was at too early a stage in its development to attract large pharmaceutical companies. And because the new technology's value had not yet been demonstrated, it was also too early to attract venture capitalists.

In July 1993, BioHybrid found partial financial relief from an "angel"—an individual investor who was motivated by the desire to develop better diabetes treatments for his ailing son. But despite this infusion of equity capital, Hayes and Chick knew that additional backing would rapidly become necessary.

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[11]Other participants included the Department of Transplant Surgery at New England Deaconess Hospital and the Tufts University School of Veterinary Medicine.

[12]Since nearly 100 million pigs are used for food every year in the United States, current pig farming operations could easily supply enough pancreatic tissue for everyone needing a transplant. Furthermore, because pig insulin is very similar to human insulin—only differing by one amino acid—the efficacy of insulin delivered with this approach would be equivalent to that of insulin currently available on the market.

BioHybrid and the Advanced Technology Program

The remedy for BioHybrid's financial difficulties came in the form of a $4.25 million ATP grant awarded in November 1993. The proposal had been a joint submission by BioHybrid and Synergy Research Corporation of Hanover, NH—although BioHybrid, Hayes said, was clearly the dominant partner. According to Hayes, Synergy has less than a five percent stake in the project, and focused primarily on engineering issues involving fabrication and production. BioHybrid brought Synergy on board as a joint-venture partner because of its demonstrated engineering skill and expertise in scaling up projects for commercial applications.

The ATP-funded project centered on the development of implantable "microreactors." Unlike the hockey puck device, each microreactor would be less than two millimeters in diameter, and could be implanted in the patient by injection, thereby avoiding difficult and risky surgery. The microreactor represented a potential solution to the critical problem inherent in any attempt at cell transplantation: the body's own immune system. Regardless of the quality of the transplanted cells, they would be rendered useless if the body's immune system rapidly neutralized them. BioHybrid proposed to encase the transplant cells in "stealth" microspheres, thereby isolating them from the immune system, and to develop techniques to keep the cells viable within the microspheres. Although this microreactor technology would initially be used for the treatment of diabetes, BioHybrid's ATP proposal emphasized that these tiny devices could also be applied when transplanting a wide variety of primary and bioengineered cells into patients. This new technology would enable innovative treatments for a variety of diseases.[13]

According to Hayes, the ATP grant was ideal for such a project. "It provided us with three years of development that we couldn't have done otherwise," he said. "The ATP grant allowed our company to move the technology toward the front door of clinical trials."

In 1994, BioHybrid supplemented its ATP funds with a $75,000 Phase I SBIR grant. The grant funded an examination of some of the manufacturing issues that were a subset of the microreactor project. BioHybrid was later granted Phase II funding. Chick and Hayes were also able to locate financial support for BioHybrid's sister company, Sensor Technologies.[14] Founded by Chick and Hayes in 1988, Sensor forged ties with a corporate sponsor in 1995. In the early years, Sensor had been funded solely by the founders; from 1993 until corporate sponsorship, the company had remained dormant.

In comparing ATP funding to corporate sponsorship, Hayes said that the ATP gave BioHybrid the opportunity to take a longer-term approach. Hayes emphasized that ATP grants provide companies with the means to bypass shortsighted commercialization goals, if more expansive R&D efforts could yield a superior technology and larger, long-term payoffs.

In retrospect, Hayes also believes that the ATP grant helped BioHybrid avoid some of the pitfalls facing many venture-backed biotechnology companies. "Venture capitalists forced many companies to go public too early, when they couldn't support the stock price," said Hayes. "The only way these companies could show progress was to display all the new people they had hired." Hayes further stressed that excessive financial resources and flexibility is an additional problem that plagues biotechnology companies that go public too soon. "Venture capitalists would force these companies to near-term liquidity," he said. "The companies end up losing focus and diversifying into areas that they shouldn't be

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[13]These microreactors have pores large enough to permit glucose, nutrients, electrolytes, and bioactive products (like insulin) to pass, but small enough to block immunocytes and other relatively bulky molecules involved in transplant rejection.

[14]Sensor Technologies is devoted to the development of non-invasive technology for monitoring metabolites, enzymes, hormones, and other bioactive molecules in patients. The first product being developed by the company is a wristwatch that can continuously monitor glucose levels in diabetic patients without the need to draw blood.

involved in—areas where their expertise is less on point and where the probability of success is by definition lower."

Although ATP funding has had many side benefits for BioHybrid, Hayes said that the company's status as an ATP award recipient did not prove as helpful as he would have guessed in raising additional funds from the private sector. "I thought fundraising would get substantially easier, but it didn't," he said. "Venture capitalists don't trust the government's stamp of approval—they want to send in their own due diligence teams." Hayes added that he was also unsuccessful in using the concept of the ATP's matching funds as a way of attracting large pharmaceutical companies. "When pharmaceutical companies consider funding us, they think in terms of full commercialization budgets which are in the magnitude of hundreds of millions of dollars," Hayes said. "Four million dollars from the ATP didn't really matter a great deal to the pharmaceutical companies."

As for the issue of whether joint ventures are an effective structure for ATP-funded projects, Hayes had only positive comments about BioHybrid's relationship with Synergy. According to Hayes, the two companies were able to avoid a lot of the bureaucratic hassles that often accompany joint ventures because both companies were small and could thus move quickly and decisively. "The principals could sit down and make all the arrangements," he said. "The only inconvenience was the physical distance between us."

On the Horizon

BioHybrid is planning to begin clinical trials in late 1998 or early 1999. Hayes said that these trials could possibly begin earlier, but that this is unlikely—given that BioHybrid is currently in negotiations with a pharmaceutical company and that it would be more favorable to wait until the negotiations are complete. According to Hayes, three or four other companies, each with different immune isolation methods, are also close to the clinical testing stage.

3A-3. Continuum Software, Inc.

A Brief Company Profile

John Mucci, Ted Tabloski, and Bob Millstein founded Continuum Software in 1994, building upon their many years of experience at Thinking Machines Corporation, a Bedford, MA-based computer company that had helped pioneer massively parallel supercomputing technology back in the late 1980s and early 1990s. All three had held senior positions at Thinking Machines and had been responsible, according to Continuum, for all of Thinking Machines' software—a total of several million lines of code.

But Thinking Machines had been a systems company (hardware and software). It had been focused primarily on building high-performance supercomputers for research, engineering and scientific, and commercial applications. This market soon proved to have a low ceiling, particularly with the demise of the Cold War and with the high entry price. With Thinking Machines' balance sheet spiraling toward bankruptcy,[15] Mucci, Tabloski, and Millstein left the company to form Continuum. Because the three founders believed that the core value of Thinking Machines had actually been in the company's understanding of parallel applications, they wanted their new company to have a very different strategic focus from that of their former employer. They planned to target the business marketplace instead of the academic arena, and thus centered their efforts on developing software for corporate applications.

[15]Thinking Machines filed for Chapter 11 bankruptcy protection in August 1994. In February 1996, following a dramatic shift in the company's market focus, Thinking Machines received a $10 million capital infusion and successfully emerged from Chapter 11 status.

Despite this fundamental difference in market focus between Continuum and Thinking Machines, Continuum's founders built the company around a core belief similar to that of their former employer: a belief in the promising future of low-cost parallel processing. Mucci, Tabloski, and Millstein emphasized that parallel computers—those with several processors (disks, etc.) that could work on computations simultaneously—had the potential to solve many of the formidable problems that arise from the vast amounts of data often required in modern business and government applications.

Continuum's founders also believed, however, that widespread use of parallel systems had been blocked by the lack of equally powerful application software capable of taking advantage of the hardware's raw power. The founders further recognized that retraining programmers in the complexities of parallel programming was a difficult and costly proposition. To address these issues, the company's goal became the provision of a software development environment in which a client's existing programming staff could harness the power of parallel platforms without having to understand the intricacies of parallel processing. Continuum planned to invest considerable resources into creating graphical user interfaces that would make the company's parallel programming tools accessible to a wide audience of software developers.

The formation of Continuum was also driven by another practical consideration: the need for "scalable" computer systems. Continuum's founders emphasized that although parallel hardware is more cost effective than traditional mainframes of comparable power, *scalable* parallel systems—which allow the user to add incremental hardware as performance needs expand—would be even more efficient. The founders further stressed that adding hardware to a scalable system was a far more cost-effective strategy for increasing system performance than modifying application software. The company therefore planned to make scalability a key component of its parallel programming environment—giving applications developed in Continuum's environment the ability to automatically adapt to changes in a system's hardware specifications.

Continuum and the Advanced Technology Program

One of Continuum's first projects, according to Tabloski, who served as the company's vice president, was to submit an ATP grant proposal. With the component-based software competition deadline right around the corner, the three founders wrote the proposal in a matter of weeks. Because the company was still in its formative stages, the process of drafting this proposal was as much an exercise in writing a business plan as it was an attempt to raise capital. Regardless of whether the proposal ended up generating financial support for the company, Tabloski and the other founders viewed it as an opportunity to further clarify their thoughts and better focus the company's direction.

But Continuum's ATP proposal proved to be more than just a useful exercise. Only one month after submitting the proposal, the company received notice that it had been selected as a semifinalist. Given the number of semifinalists and the amount of money on the table, said Tabloski, "We thought we would probably have to completely screw up the interview not to get the money." In the end, Continuum was awarded a three-year, $2 million grant.

Because Continuum was selected for an ATP award at a very early stage in the company's development, Tabloski said that prior to the award the founders had only conducted a very preliminary search for private funding sources. And after receiving the grant, Continuum's founders shifted their time and energy away from fundraising altogether, and focused their efforts on research and development with the company maintaining "only low-level contact with potential angels." The founders paid for the project's indirect costs as well as the company's other expenses out of their own pockets.

The ATP funds also allowed Continuum to shape the research and development process as the company saw fit and to steer clear of funding sources which might come with substantially more strings attached. As a result, Continuum was able to take what Tabloski calls "a technologically aggressive

systems approach"—characterized by a broader research agenda, more challenging technological goals, and an emphasis on developing sophisticated graphical interfaces to make the software easy to use. "We took an aggressive approach with respect to technology, which resulted in problems that took longer to solve than venture capitalists would have been happy with," said Tabloski. "What we now have is broader than just scalable business applications. Our broader research agenda has resulted in a broader platform and a consequently larger market."

In addition to expanding the scope of the company's ATP-funded project, Continuum also branched out into other areas. One creation, "Fido the Shopping Doggie," was the brainchild of a member of Continuum's technical staff. The purpose of Fido was to facilitate on-line shopping by combining a centralized database of vendor products and prices with a simple searching mechanism to sort through the entries. Fido's search engine could be accessed directly via the World Wide Web, and the site received publicity in several on-line and print publications. According to Tabloski, Fido was meant to be a demonstration of machine learning and database mining, and because it was only a sidebar to Continuum's core parallel processing software technology, eventually the company stopped updating or servicing the site, and thus "let it rot over time." While Continuum has no plans to pursue the commercialization of Fido on its own, the company has licensed elements of the Fido technology to a company with a larger Internet presence.

On the Horizon

Currently, beta testing of "MultiPly"—the software prototype that embodies Continuum's ATP-funded research—is underway with additional beta users to be located and testing to be arranged. Even during this initial testing period, however, the company has remained focused on continuing its research and development activities and extending the capabilities of the technology. And with Continuum's ATP-funded project concluding in the coming months, the company has hired a salesman to prepare for the product launch of MultiPly, scheduled to take place in the beginning of 1998.

Continuum is also pursuing a large round of venture financing to raise money for the sales and marketing costs of accelerating growth. In 1997, the company got the process underway with what Tabloski called, "a little round of venture financing, just to get things going." According to Tabloski, the venture capital firm now involved with the company would have never invested at the stage when the ATP did. "It was important to the venture capitalist that we had demonstrable stuff," Tabloski said. "Before we didn't, now we do."

3A-4. Cynosure, Inc.

A Brief Company Profile

Dr. Horace Furumoto and Harry Ceccon founded Cynosure Inc. in 1991. Furumoto had just been ousted from the helm of Candela Laser Corporation—the company he and Ceccon had established 21 years earlier. Furumoto's termination by the board of directors had been in his view the result of a rift that had formed between him and several of Candela's senior managers over the strategic direction that the company should follow.

After leaving Candela, Furumoto proceeded to form Cynosure, taking many of his top technical managers with him.[16] To finance product development, Furumoto raised $3.3 million from private investors. To fund the new company's research agenda, Furumoto applied for and received a Phase I SBIR grant from the National Institute of Health. The new SBIR grant was a continuation of Furumoto's long history with the SBIR program. During the course of his career, he had helped secure twenty-three SBIR grants, including nine Phase II awards.

[16]When Furumoto departed from Candela, Ceccon also left the company to help him establish Cynosure.

As he had done at his previous company, Furumoto centered Cynosure's market focus on designing medical lasers. These devices are used by hospitals, doctors, and clinics in a variety of fields including urology, ophthalmology, and dermatology. Cynosure's lasers are used to treat birthmarks, warts, and leg veins, as well as to remove tattoos and unwanted body hair.

Cynosure's emergence into the market, however, was complicated by the terms of Furumoto's separation from Candela. A "Noncompetition, Confidentiality, and Inventions Agreement" specified that Furumoto could not compete with Candela in the medical laser market until April 15, 1992. With this restraint in place, Furumoto set out in Cynosure's first year to develop alternatives to Candela's medical laser technology. Soon after the end of the noncompetition period, Cynosure introduced a triad of FDA-approved devices that were in direct competition with Candela's lasers.

But the introduction of Cynosure's new lasers created a legal dispute with Furumoto's former company. In November 1992, Candela filed suit against Cynosure for infringement on light amplifier technology on which Candela held a patent.[17] Candela also contended that Cynosure had engaged in false advertising, misappropriation of trade secrets, breach of contract, and unfair competition. In an amended complaint filed in May 1993, Candela further alleged that Cynosure had incorporated a dye circulation process similar to that described in a 1988 patent held by Candela.[18] And in July 1993, Candela tacked on an additional charge. This amendment alleged that Cynosure's laser not only violated Candela's proprietary patents, but also encroached on a patented dye regeneration technology that Candela had licensed.[19]

As a result of these allegations, Cynosure was placed in a precarious position: One of the lasers, the "PhotoGenica V", was the source of 65 percent of Cynosure's $5 million in revenues, and a judicial decision against the company would have been a major setback.[20] Furthermore, the mere existence of the lawsuits had disrupted Cynosure's core business operations. The pending legal dispute had made the company less attractive to potential investors and had created some hesitation among potential customers.[21] Despite these difficulties, Cynosure still managed to attract substantial inflows of capital. According to Furumoto, although it took some doing, the company was able to raise another $3.4 million from venture capitalists and institutional investors during these trying times.

As for the legal dispute itself, although Furumoto had hoped to avoid a confrontation, he had prepared early for such a scenario. Upon his departure from Candela, Furumoto purchased the scientific division of the company—what Candela's remaining management had considered only to be a sidebar to the company's core medical laser devices. But Furumoto had wanted the division because it contained the intellectual property on which Candela was based. According to Furumoto, by purchasing Candela's scientific division, he legitimized Cynosure's claim to its new generation of lasers, and deflected Candela's eventual charges of misappropriation of trade secrets, breach of contract, and patent infringement.

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[17]The Patent and Trademark Office issued Furumoto a patent in 1991 for his application of curved optics to dye lasers (U.S. Patent No. 5,066,293: "Light Amplifier and Method of Photothermolysis"). As is standard practice, Furumoto assigned the patent to his employer, Candela.

[18]In 1988, Furumoto had filed a patent on an improved dye circulation process, which he had also assigned to Candela (U.S. Patent No. 4,977,571: "Dye Laser Solution Circulation System").

[19]Candela had licensed a patented dye regeneration process from Chicago-based Gaelis Corporation (U.S. Patent No. 5,109,387: "Dye Laser System and Method").

[20]*Candela Laser Corporation v. Cynosure, Inc.*, U.S. Federal District Court for Massachusetts (filed 1992), docket no. 46.

[21]"Candela loses patent fight to founder," *The Boston Herald*, March 23, 1994, p. 34.

After two years of costly litigation, the courts sided with Cynosure. U.S. District Court Judge Rya Zobel ruled that Cynosure's laser did not infringe on Candela's light amplifier patent. The judge further ruled that the dye regeneration patent licensed by Candela was, in fact, invalid.[22] When Candela appealed the decision, the U.S. Court of Appeals for the Federal Circuit affirmed the lower court's ruling. Cynosure emerged from its legal battles unscathed. According to Furumoto, Cynosure's relationship with Candela has been improving with time.

And despite this protracted legal dispute, Cynosure was able to achieve rapid growth. In 1996, the company was ranked No. 112 in *Inc.* magazine's list of the 500 fastest-growing private companies in America. Cynosure's sales grew from $626,000 in 1991 to more than $23 million in 1997.

Cynosure and the Advanced Technology Program

Although Cynosure submitted its first ATP proposal shortly after the company was formed in 1991, it did not win an award until the end of the following year. According to Robert Rediker, who served as the principal investigator for the company's eventual ATP-funded project,[23] Cynosure's initial proposal suffered from a misdirected business plan.

After examining the shortcomings of the initial proposal, Cynosure submitted a revamped version in 1992. This time the company won nearly $2 million in ATP funding. Like the company's previous proposal, Cynosure planned to explore how a series of semiconductor lasers could be combined to get one powerful beam. Diffractive optics would be used to correct for minor inaccuracies in the alignment of individual lasers. These faults that could substantially degrade the performance of the entire system.[24]

According to Rediker, in writing the new and improved proposal Cynosure stopped treating the ATP like other grant solicitations. "Instead of talking about our chances for success, we decided to emphasize that the project was very high risk," Rediker said. "Rather than focus on the areas we were confident about, we felt that the proposal needed to highlight how difficult the project would be."

Cynosure's ATP-funded research concluded in 1995. In assessing the overall experience, Rediker emphasized that Cynosure had faced unexpected problems in the supposedly low-risk areas,[25] but had been successful in the project's high-risk tasks. On the other hand, Furumoto stressed that from a commercialization perspective the project had been far from a success. "In our particular project, we did not meet any of our promised goals," Furumoto commented. "The work was scientifically challenging, we enjoyed it, and we generated a good paper, but alas, no commercial product."

According to Furumoto, the project's commercial shortcomings stemmed from the ATP's excessive focus on high-risk technology—an emphasis that Furumoto believes detracted from both the company's and the agency's commercialization objectives. "In our case, the relaxing of the reasonable chance of success requirement of standard contracts led to an overly complex proposal," Furumoto said. "We got a

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[22]In November 1993, Candela had withdrawn its claim of patent infringement on the dye circulation patent, as well as its allegations of false advertising, misappropriation of trade secrets, breach of contract, and unfair competition. The judge, therefore, only had to rule on the claims of patent infringement involving the light amplifier and dye regeneration patents.

[23]Rediker was one of the co-inventors of the semiconductor diode laser. Although he continues to be involved with Cynosure, he is currently retired.

[24]This use of diffractive optics was deemed by Rediker to be the most challenging aspect of the project. Not only did the faults have to be identified and quantified, but if real-time "prescriptions" for each lens were to be made, then this process had to occur rapidly.

[25]Chief among these unanticipated problems was the inability of Cynosure's suppliers to deliver the high-quality custom lenses that were essential to the project.

contract for the sake of getting a contract and did not reach commercialization. There is no controversy about innovation, but high risk somehow must be tempered with some chance of success."

In comparison, Furumoto said that Cynosure recently initiated a new area of research with nearly the same end goal as the ATP-funded project, but with a higher probability of success. "The reason the company supported the program," he said, "is that it was innovative and clever to the point that it was low risk." Furumoto added that because the Federal grant process is typically too slow, Cynosure's strategy is to avoid using Federal grants and contracts to finance research with near-term product applicability.

Although the ATP-funded project did not lead directly to product development, both Furumoto and Rediker agreed that the funding led to additional government grants. Because research in the medical laser field is extremely equipment intensive, the diagnostic equipment obtained through the ATP project proved critical for Cynosure in obtaining government funding that was dependent on already having access to expensive and specialized equipment. According to Rediker, government agencies were also attracted to the idea of allocating grants that would build upon work that the ATP had already funded. "The ATP was not as helpful in getting private investors," Rediker said, "but the program made it possible for us to obtain a lot of other government R&D money." Furumoto noted, however, that although the ATP grant led to more government contracts, Cynosure is "still far from getting a commercial product out of all of these contracts."

On the Horizon

Cynosure is currently engaged in two projects, funded by SBIR and STTR grants, which follow up on the initial ATP-funded research. Instead of exploring diffractive optics, the research builds upon elements of the ATP project that dealt specifically with diode laser technology.

Although Cynosure has no immediate plans to commercialize the diffractive optics portion of its ATP-funded research, the company hopes that the knowledge gained about semiconductor diode lasers will impact Cynosure's next generation of devices. While flashlamp-excited alexandrite lasers are the company's current core technology, diode lasers could become the company's core technology of the future.

In the meantime, Cynosure is continuing to improve its existing laser designs, with a dye laser designed for hemostasis currently undergoing clinical trials. In the past year, Cynosure also introduced two new flagship lasers—for hair removal applications and large leg vein treatments—to its PhotoGenica brand line. According to Furumoto, the company expects continued growth in its hair removal laser, as revenues for the product have tripled during the last three quarters. Cynosure charges premium prices for its products to offset the company's substantial marketing and R&D expenditures.

3A-5. Kopin Corporation

A Brief Company Profile

Founded in 1984 by John Fan, Kopin Corporation develops and manufactures advanced semiconductor materials and electronic digital imaging devices. The company was the outgrowth of research conducted at a MIT laboratory into a new field called "wafer engineering." The fundamental concept behind this technology is that dissimilar materials can be manipulated and combined to create optimal products.[26]

[26]More specifically, single crystal semiconductor materials can be formed on dissimilar substrate materials—such as gallium arsenide on silicon wafers. In addition, materials may be layered to form optimal thicknesses and combinations for high performance circuit devices.

After licensing the technology from MIT, Kopin's scientists and engineers spent the remainder of the 1980s learning to master the intricacies of wafer engineering—techniques that would form the backbone of the company's endeavors. In the early 1990s, Kopin began to develop and market commercial wafer products, capitalizing on opportunities involving portable communication and information devices. The company's most successful commercial wafer product, introduced in 1995, has been a gallium arsenide heterojunction bipolar transistor (HBT) wafer. These wafers are used by manufacturers of gallium arsenide integrated circuits, power amplifiers, and other enabling mechanisms. They have been employed particularly in the production of cellular telephones, advanced pagers, and other portable communication devices that require very high frequency circuits. Currently, several million cellular handsets utilize Kopin's wafer product. The company believes that by combining high performance and a compact design with competitive manufacturing costs, Kopin's HBT circuits will be able to penetrate applications historically served by older technologies.

Kopin's newest commercial product, the "CyberDisplay 320,"™ is related to the liquid crystal flat-panel display technology found in portable computer screens. The product, introduced in April 1997, was made possible by a key wafer engineering breakthrough which allowed Kopin scientists to "lift" thin semiconductor layers off the substrate used for circuit fabrication, and then to bond these layers onto different substrates for enhanced performance.[27] According to company literature, by using wafer engineering, Kopin can fabricate displays that are 1,000 times smaller and that consume 100 times less energy.[28] As a result, Kopin's ultra-small, high-density imaging devices feature performance characteristics superior to commercially available cathode ray tube (CRT) and liquid crystal display (LCD) devices. Furthermore, Kopin states that its product is capable of achieving these high standards at comparable or lower manufacturing costs by virtue of its wafer engineering processes.

The potential impact of these core technologies has attracted considerable financial resources to the company during its 13-year history. According to the VentureSource database, Kopin raised $10.5 million in venture capital during the company's early years, most notably from DSV Partners, The Vertical Group, and Venrock Associates. In April 1992, Kopin completed a $15 million IPO, which pegged the company's market value at $65.5 million. More recently, Telecom Holding Co., Ltd., an affiliate of the CP Group of Thailand, made a $27.1 million equity investment in Kopin. These funds are being used to expand Kopin's manufacturing capabilities for flat panel displays.

But despite these inflows of capital, Kopin had yet to achieve profitability. In 1996, the company posted a net loss of $9 million on sales on $18 million, compared with a net loss of $6.6 million on sales of $15.8 million in 1995. Kopin attributes these losses to the company's continued reinvestment in wafer production capacity and in CyberDisplay production processes. During the past five years, Kopin's annual R&D expenditures have been roughly equal to its net sales.

Kopin and the Advanced Technology Program

Due to Kopin's large R&D budget, obtaining outside grants to cover a substantial portion of these costs has been critical to the company's research activities. According to Ollie Woodard, a project manager with the company, roughly half of Kopin's research funding comes from government grants.

"We make several million dollars a year from our wafer business, but it is not sufficient to support all of our R&D efforts," Woodard said. "Government programs make it possible for us to conduct research in advanced technology areas we wouldn't otherwise be able to examine." Woodard added that because

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[27]Kopin first applied this technology in a series of contracts funded by the Defense Advanced Research Projects Agency (DARPA).

[28]Kopin's CyberDisplay is less than one-fourth the size of a dime, but is capable of showing the same amount of information content as a notebook computer screen.

of the many military applications for Kopin's imaging devices,[29] the Defense Advanced Research Projects Agency (DARPA) has historically been Kopin's largest R&D contributor.

And even though DARPA has dominated Kopin's research agenda, Woodard said that the ATP has also had a substantial influence. Kopin's first ATP grant, a $2.8 million award, funded a collaborative effort with the Microelectronics and Computer Technology Corporation (MCC)[30]—a consortium of large companies interested in technology packaging issues. The goal of the project was to show that multi-film modules, technology which allows circuits to be packed closer together, could potentially produce very high circuit packaging densities—thus making the technology a viable alternative to miniaturization. To demonstrate this, Kopin and its partners constructed a high-resolution flat-panel display using "thin film" silicon lift-off circuits. The display was designed to be purely a demonstration tool: The fundamental objective was to show how multiple thin films could be densely placed as well as interconnected with one another.

In subsequent projects, thin film circuitry has been superimposed on a variety of media to produce flexible circuits, stacked 3-D circuits, and other innovations. According to Woodard, who served as the project's principal investigator, the "extremely pre-competitive" nature of the research made the project especially appropriate for a consortium—a structure better suited for exploring widely applicable technologies than for actually developing products.

This three-year project was completed in 1995, and a related project is currently being funded by DARPA. In this new project, Kopin is expanding its understanding of three-dimensional circuits by stacking thin film circuits on top of image sensor circuits to achieve high-speed image recognition and tracking. Woodard emphasized that although the DARPA grant was not predicated on the results of Kopin's ATP-funded project, the company used its ATP track record in circuit film transfer as certification that the proposed structures could, in fact, be made. Woodard also said that because the initial ATP-funded project was not critical to Kopin's core areas of interest at the time, the research probably would not have been completed in a timely manner without ATP support.

In the company's second ATP project, jointly proposed with Philips Electronics North America and MIT, Kopin is developing next-generation projection display technology. The goal is to produce higher resolution over larger areas than conventional cathode ray tubes by controlling an overlying layer of liquid crystal with a densely patterned thin film of silicon-based circuitry. Compared to Kopin's first ATP project, this $6.1 million ATP grant has funded research that is much closer to the commercialization phase. Kopin's thin film lift-off process will be used to produce sophisticated displays that have low manufacturing costs—making the technology accessible to the large consumer markets anticipated for such products as high-definition television (HDTV).

The final HDTV prototype demonstration is scheduled for October 1998, with prototype testing to follow this demonstration. Despite the deep pockets of Philips, Woodard is doubtful that the electronics giant would have funded this research without the ATP's financial support. "Three years ago, Kopin's technological advancements and experience in the field probably would not have been convincing enough to persuade Philips to invest at that time," Woodard said. "The cost sharing concept provides good leverage in convincing partnering companies that your technology is real."

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[29]One product, for example, incorporated Kopin's imaging technology into a head-mounted display system for military applications.

[30]The ATP grant was actually awarded to The American Scaled-Electronics Consortium (TASC). This consortium was composed of Kopin and the MCC-affiliated companies. Kopin, however, coordinated the project.

On the Horizon

Kopin is currently tripling its manufacturing capacity for wafer-engineered gallium arsenide materials to accommodate growing customer demand. The company is also focused on continued improvement in manufacturing efficiency and cost reduction. Kopin's goal is to provide wafer materials that enable higher performance circuit solutions at costs competitive with alternative gallium arsenide and silicon technologies.

Another noteworthy development has been Kopin's announcement of a multi-million-dollar CyberDisplay agreement with Siemens Wireless Terminals, a division of Siemens Business Communications Systems. Under the terms of the agreement, Siemens will license Kopin technology for wireless phone applications, and will purchase CyberDisplay components from Kopin. The companies also plan to engage in joint product development.

In addition, Kopin is shipping its CyberDisplay devices in sample quantities to electronic product manufacturers for evaluation. Positive evaluations by several companies have led to new product design projects that will incorporate the technology.

The hope is that these undertakings, along with recent increases in product sales, will initiate Kopin's transition from a developmental stage organization into a commercially focused, growth company.

3A-6. Kurzweil Applied Intelligence, Inc.

A Brief Company Profile

Even before personal computers became a part of everyday life, Kurzweil Applied Intelligence was developing computer-based voice recognition systems for healthcare and business applications. Raymond Kurzweil established the company in 1982, and ever since its founding, the objective of Kurzweil AI has been to develop software applications that enable users to input text and data by speaking into a microphone.

While Kurzweil AI's early systems required proprietary hardware and had extremely limited vocabularies, the company's most recent generation of voice-recognition interfaces run on Intel-compatible computers and feature a 60,000-word capacity. These interfaces include the "Kurzweil VOICE" line of personal computer applications and the "Kurzweil Clinical Reporter." The company's VOICE applications combine discrete speech technology—in which users must briefly pause between each dictated word—with continuous digit recognition capabilities, which allow users to rapidly dictate lists of numbers into spreadsheets and databases. VOICE products are also capable of adapting to the user's speech and language patterns so that accuracy improves over time.

The bulk of the company's revenues, however, come from sales of the Kurzweil Clinical Reporter. The Clinical Reporter allows physicians to archive notes about patients and create standardized reports by dictating the information to a computer. The application is equipped with a specialized medical vocabulary, and is designed to replace the transcription service companies that doctors typically use to transcribe their tape-recorded clinical notes. According to company literature, Kurzweil AI's system can save hospitals from 70 to 100 percent in transcription costs while reducing report turnaround time from days to minutes. With systems in use at over 500 medical institutions, the Kurzweil Clinical Reporter is one of the market leaders for medical reporting systems.

To finance the development of these products, Kurzweil AI has been the recipient of more than $31 million in venture financing—most notably from Aeneas, Oxford Partners, and Xerox Venture Capital.[31]

[31]According to data from VentureOne's VentureSource database.

In 1993, Kurzweil AI graduated from the venture capital ranks with a $21 million IPO on the NASDAQ Stock Market (KURZ).

The amount of money raised, however, was not the most significant aspect of the company's IPO. In a high-profile scandal, three senior Kurzweil AI managers—president Bernard Bradstreet, vice president Thomas Campbell, and treasurer Debra Murray—were found guilty of conspiracy, securities fraud, and falsifying company records. The court found that Bradstreet, Campbell, and Murray deliberately misled the investing public into believing that the company was making a profit when, in fact, it was losing money. More specifically, the company's leadership recorded sales for potential customers who had not yet signed final sales agreements and booked millions of dollars in phony sales, shipping the goods to a local warehouse where they gathered dust. When the bogus sales numbers were finally uncovered, the company's stockholders sued. Kurzweil AI agreed to settle, and the company ended up paying $7.25 million in stock and another $250,000 in cash to investors who bought equity in the company between its August 1993 public offering and its April 1994 announcement of bookkeeping problems.

In the aftermath of the scandal, new leadership assumed the helm of the company. Although the new managers were successful in instituting new accounting practices and in restoring the Kurzweil AI brand name, the company continued to lose money. In 1994 and 1995, Kurzweil AI posted net losses of $11.2 million and $2.6 million on net sales of $12.4 million and $9.4 million, respectively. Similarly, in 1996, the company lost $4.1 million on net sales of $8.5 million.

But despite Kurzweil AI's lack of profitability, in June of 1997 Belgium-based Lernout and Hauspie Speech Products (L&H) acquired the company for $53 million in cash and stock. A primary objective of the L&H acquisition was to accelerate the development of continuous speech dictation products by combining the technologies and resources of both companies. A further objective was to help L&H gain a foothold in the medical reporting market while also expanding Kurzweil AI's ability to reach a worldwide audience with its product offerings. In addition, the deal provided cash-starved Kurzweil AI with a badly needed infusion of capital—including a $1.5 million line of credit to finance the company's working capital needs prior to the closing of the acquisition.

Kurzweil AI and the Advanced Technology Program

If the company's promotional materials are any indication, Kurzweil AI—the recipient of two ATP grants—is not shy about utilizing the ATP's stamp of approval as an indicator of its technological potential. No deeper than the third paragraph of its corporate information sheet, Kurzweil AI describes in detail its ATP projects and proclaims that the program has deemed Kurzweil AI's technology "central to the competitiveness and efficiency of American business and healthcare."

In the company's first ATP project, titled "Applied Spoken Language for Computer Applications," Kurzweil AI developed technology that enables users to control software applications through spoken "natural language" commands. The three-year project (which was awarded a $1.8 million ATP grant in 1993) was especially challenging, according to Vice President of Research Francis Ganong, because it involved the added task of not only recognizing, but also interpreting and acting upon, continuously spoken commands. Although the project floundered in its second year due to distractions from within the company,[32] Ganong stressed that the project turned out to be a great success. As an outgrowth, Kurzweil AI will soon be shipping an application called "VoiceCommands"—the commercial embodiment of the project. The application is designed to increase user productivity by recognizing naturally spoken commands to edit and format Microsoft Word documents. In addition, at the November 1997 COMDEX conference, a showplace for new technological products, Kurzweil AI introduced a large vocabulary

[32]In addition to the securities fraud scandal, other distractions included a project manager who had to be replaced during the course of the project.

dictation machine with natural language command and control capabilities. Kurzweil AI stressed at the conference that these capabilities embody the key distinguishing feature between its recognizer product and those of its competitors. According to Ganong, both of these products are promising stepping stones toward a full-fledged continuous dictation product.

In Kurzweil AI's second ATP-sponsored project, the company is addressing data gathering, storage, and access issues in the healthcare community. The project was awarded a $2 million ATP grant in 1995, and Ganong said that the project was compressed into a two-year period because of fears that Congress would eliminate ATP funding. The objective of the project is to put information in a structured format that streamlines the cumbersome data manipulation process that occurs after a doctor archives clinical notes. To do this, Kurzweil AI is using the Structured Generalized Markup Language (SGML) standard to create a medical reporting system with a voice, pen, and mouse interface, as well as the capability to communicate with any medical database. The goal is for the software to be able to output data in a way that is easy to integrate with existing medical systems.

Comparing Kurzweil AI's two ATP-funded projects, Ganong emphasized that the first project had a much greater element of scientific risk because researchers were trying to solve a fundamental technological problem. The second project, on the other hand, deals less with technological innovation and more with adapting existing technology to fit the information chaos that tends to characterize modern medicine.

Ganong said that the impact of ATP funding was especially noticeable on Kurzweil AI's first ATP project because of its high element of risk. "The project was certainly ambitious for the company. We were at the very edge of our competence," said Ganong. "Kurzweil does not have huge reservoirs of seed money, and has short cycles of product development. The ATP grant helped us to conduct research in an important area that wasn't essential to the company."

Ganong added that without the ATP funds, Kurzweil AI would have focused its efforts on continuous speech dictation and would probably not have devoted resources to continuous command and control research. He also said that because of Kurzweil AI's unique circumstances, the ATP funding helped keep the company's research agenda moving forward, even when "the management went away." Without the ATP, he said, VoiceCommands would not exist.

On the Horizon

The most pressing objective for the new Kurzweil AI and L&H conglomerate is to catch up with competitors, such as Dragon Systems and IBM, that have already released continuous dictation products. The companies also plan to build upon Kurzweil AI's successful medical reporting business by exploring legal, law enforcement, and financial applications. The goal is to show potential users that voice recognition software is not just a novelty, but an actual productivity tool.

Along with technological advancement, price reduction continues to be a major objective. Expansions in computer processing power combined with progress in software technology have already dropped prices for discrete speech-recognition programs below one hundred dollars.

In its ongoing ATP project on structured medical information, Kurzweil AI has already developed a prototype. Beta testing was scheduled to begin in November 1997.

3A-7. Torrent Systems, Inc.

A Brief Company Profile

Privately held and based in Cambridge, MA, Torrent Systems (formerly Applied Parallel Technologies, Inc.) was founded in early 1993, and existed for 18 months before receiving ATP funding. During its

infancy, the company consisted solely of the two founders, Rob Utzschneider and Edward Zyszkowski. While Zyszkowski brought to the company the necessary technical know-how, Utzschneider, formerly the vice president of marketing at a parallel-processing hardware vendor, provided the business acumen.

The company was founded upon the idea that converting enormous transaction databases into meaningful information often requires data processing power in excess of conventional mainframes, minicomputers, and workstations. Torrent's founders further believed that parallel computers—machines with multiple processors that can break a problem into pieces and address those pieces simultaneously—represented the best and most cost-effective way to address these performance issues. By harnessing the power of parallel processing, they planned to develop more sophisticated "database mining" techniques—methods that would better enable organizations to extract value from large volumes of data.

But Torrent's founders also realized that the application of parallel processing technology had been constrained by the limited supply of programmers with the knowledge base necessary to exploit the hardware's capabilities. Because parallel programming is inherently difficult and requires specialized expertise and training, many businesses ended up shying away from the technology due to the added risk and expense. To dramatically reduce these development bottlenecks, Torrent intended to use object-oriented design—a programming approach that encapsulates data within reusable objects—to insulate software developers from the need to understand parallel architectures. This would enable software developers to build applications for the emerging class of parallel computers without having to learn new languages, algorithms, or programming paradigms.

During the company's early years, the founders spent most of their energy conducting background research on software architecture and market opportunities. They also spent time cultivating relationships with leading systems integrators, hardware vendors, and end users. As their business plan began to crystallize, Utzschneider and Zyszkowski started to search for venture capital funding. But according to Utzschneider, raising capital proved to be an extremely difficult task because parallel programming was deemed by most investors to be an extremely risky technology with a precarious commercial market.[33] "A lot of venture investors saw hardware failures in parallel computers, and were consequently reluctant," said Utzschneider. "It was difficult to get a venture capital firm interested when companies back then didn't yet have the computers needed to use the software."

As a result, Utzschneider and Zyszkowski broadened their search to include government funding sources. They first examined the SBIR program, but concluded that the structure of the program was not a good fit for the demands of their technology. According to Utzschneider, a Phase I SBIR award (at the time no more than $50,000) was not a large enough sum to significantly advance their research. And even if the company did win a Phase II award, they still would need substantially more capital than the $500,000 Phase II funding ceiling would permit.

Torrent and the Advanced Technology Program

The Advanced Technology Program was immediately attractive to Torrent's founders because they could apply for as much as $2 million. Moreover, the government would not take a chunk of their equity stake in the company. And ATP funding would provide Torrent with the opportunity to develop its technology to the point where the company could attract private capital to fund product commercialization.

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[33]In the early 1990s, investors had suffered losses from a series of high-profile failures by "massively parallel processing" (MPP) hardware vendors. The most notable of these failures were Thinking Machines Corp. and Kendall Square Research Corp. (both of Cambridge, MA). The demise of these parallel hardware vendors had been the result of decreases in government subsidies (due to the end of the Cold War), the lack of acceptance by commercial users, and increased competition from more established companies and alternative technologies.

Torrent first submitted a ten-page proposal to the ATP's 1994 general competition, but the proposal did not garner ATP support. According to Utzschneider, the rejection was likely a consequence of a competition "that was so general, it was hard to get anyone's attention." Despite this setback, in May 1994 Torrent submitted a new pre-proposal to the ATP's component-based software competition. Because this new competition specified judging criteria that was custom-tailored to a particular industry, Torrent's founders felt they had a much higher probability of success in this focused contest than in the general competition. Furthermore, the founders believed that writing a proposal would be a much simpler endeavor now that the ATP had outlined a detailed proposal framework that took into account the specific demands of the technology.

By mid-June, the ATP had responded to Torrent's initial pre-proposal and had encouraged the company to submit a full proposal. The founders spent the remainder of June and all of July drafting this proposal, focusing special attention on adapting the company's R&D plans to better meet the ATP's detailed component-based software requirements.

In October 1994, Torrent was notified that it had been awarded an ATP grant of nearly $2 million for the proposed three-year project. In addition, the ATP funding set the stage, albeit indirectly, for a partnership between the public and private sector. North Bridge Venture Partners of Waltham, MA complemented the ATP grant with another $500,000 in seed funding to cover the project's indirect costs. Before receiving the ATP and venture capital funding, Torrent had been financed entirely out of the pockets of the founders with no appreciable revenues generated.

According to Utzschneider, the ATP grant was essential in getting the venture capital support. "We felt that the ATP grant was a very strong signal to the venture capital firm that this is a good technology," said Utzschneider. "We wouldn't have gotten the venture capital funding without the ATP." In fact, North Bridge had been optimistic compared to other venture capitalists that had reviewed Torrent's business plan. Utzschneider said that several other venture investors had deemed Torrent far too risky a prospect, even assuming that the ATP was willing to cover the company's direct R&D costs.

In assessing the level of the ATP's due diligence, Utzschneider called the evaluation process "quite competitive and thorough." In comparison with the due diligence of the venture capital industry, however, Utzschneider stressed that the ATP had a very different focus. According to Utzschneider, "90 percent of the evaluation was about the technology," which was in sharp contrast to a venture capitalist's emphasis on the business opportunity.

The ATP grant and the first stage venture capital funding met Torrent's financial needs until the second quarter of 1996. At that time, Torrent began negotiating with North Bridge Venture Partners and Oak Investment Partners of Stamford, Connecticut to provide $3.2 million of additional venture financing. In essence, although venture investors had been willing to fund the indirect costs, product development, and commercialization of Torrent's ATP-funded prototype, they had not been inclined to fund the company's initial high-risk research and development.

Along with receiving the additional venture financing, Torrent also underwent major structural changes. Zyszkowski left Torrent. His replacement, Michael Beckerle, brought more than 10 years of research experience in data-flow architectures, parallel processing, and software engineering. Furthermore, in August, the company appointed Allen Razdow as the president and CEO. Razdow had previously served as cofounder and chairman of Cambridge, MA-based Mathsoft, Inc., a maker of technical calculation software. And with Razdow now at the helm, Utzschneider relinquished his CEO position and assumed the role of vice president for market development, thereby completing Torrent's professional management team.

According to Razdow and Utzschneider, these changes were initiated in part to address the concerns of the company's venture capital investors. Restructuring such as this is a common occurrence when companies receive venture capital backing and is important for creating profitable, commercially viable businesses.

On the Horizon

With its new hierarchy in place, Torrent has graduated from the ATP. In February 1997, Torrent released "Orchestrate 2.0," an improved version of its flagship product. In July, the company announced a strategic partnership with IBM. In 1998, Torrent intended to continue expanding the availability of Orchestrate on a wider range of hardware platforms and plans to broaden the extent of its corporate partnerships through the company's channel alliance program. Major companies that have used Torrent software include United Airlines and Citicorp.

"At a core level," Utzschneider said, "without having received the ATP funds, the company would not be where it is today."

B. Insights from Case Studies

Introduction

This final chapter highlights the major themes of our case interviews and uses these insights as a springboard for evaluating the experience of small, high-technology companies participating in the Advanced Technology Program. Although the individual case studies focused on interviewee comments, in this portion of the chapter the opinions of individual companies take a back seat to our own analysis.

In general, our analysis leads us to two fundamental conclusions. First, the Advanced Technology Program has substantially expanded and enhanced the R&D activities of our seven-company sample. Second, the effectiveness of the ATP could be improved by making program adjustments in two key areas, the selection of awardees and the treatment of commercialization of projects by awardees.

The report that follows is divided into four sections. The first section discusses the strengths of the Advanced Technology Program as revealed through our interviews with seven ATP awardees. The second section analyzes elements of the ATP that could be modified to improve program efficiency and effectiveness. The third section examines three important issues for further study: due diligence, "signaling" effects, and industry targeting. The fourth and final section summarizes our findings.

Strengths of the Advanced Technology Program

ATP funding has had a substantial effect on the R&D activities of each of the seven companies we interviewed. Most of the companies felt strongly that they could not have pursued their particular research challenges as quickly or as thoroughly without the ATP. "Everything we have been able to achieve," said one interviewee, "in some sense can be traced back to the ATP."

A primary way that the ATP was able to do this was by "incubating" young companies whose technology was too early-stage to attract private capital. ATP funding provided the opportunity for these companies to develop technology, construct prototypes, and thus demonstrate the value of their ideas to potential investors. Without the ATP, several of the companies we interviewed would either not exist at all, or else would be substantially further behind in the research and development cycle. In fact, the most dramatic program results—situations in which ATP funds may very well have made the critical difference—occurred when ATP grants were awarded to smaller, start-up companies. Such anecdotal evidence suggests that the ATP helps smooth over imperfections in the financial markets for young, technology-intensive firms.

Furthermore, the ATP's ability to incubate promising, technology-driven companies has become all the more important due to trends in the venture capital industry. As a consequence of a 1979 amendment to the "prudent man" rule, in which the U.S. Department of Labor essentially reversed an earlier ruling that had prohibited private pension funds from investing in high-risk assets (Gompers [1994]), pension fund managers have poured substantial funds into venture capital firms.[34] But because pension fund managers are evaluated to a large extent on the basis of their short-term returns, venture capitalists, who typically raise new funds every three to four years, have been increasingly pressed to show better short-run performance.[35] As a result, the venture capital industry has committed more resources to late-round financing, where projects are lower risk and have more reliable returns in the near term. This shift in venture capital investment patterns has increased the funding bottleneck for early-stage firms.

Trends in venture capital fund size have also added to this early-stage funding bottleneck. As the venture industry has grown, the average fund size has increased, from $30 million in 1985 to $122 million in 1996.[36] The dramatic increase in fund size is largely due to the demands of institutional investors. Because investments in venture funds (structured as limited partnerships) are often time-consuming to negotiate and monitor, institutions prefer making relatively large investments, typically in chunks of $10 million or more. At the same time, governance and regulatory considerations cause investors to limit the share of the fund that any one limited partner holds. To accommodate both of these needs, venture organizations typically raise funds that are quite large in size. But because each firm in a fund's portfolio must be closely scrutinized (a venture capitalist is usually responsible for no more than a dozen investments), larger fund size typically leads to larger individual investments rather than to expansions in the number of portfolio firms. Many venture organizations are consequently unwilling to invest in very young firms that only require small capital infusions.[37]

Of course, the market itself has tried to compensate for the move away from early-stage investment. Attempting to capitalize on the existence of promising early-stage opportunities, some venture capital firms have decided to specialize in start-up companies. Such first-time and seed funds have witnessed a strong growth in fundraising. Similarly, more established funds have created incubator and "entrepreneur in residence" programs. Despite these and other counterbalancing effects, the impact on market imperfections may be modest.[38] The ATP, therefore, has a very significant role to play in alleviating these types of financial bottlenecks.

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[34]Even after this policy shift, private pensions did not invest in venture funds in significant numbers until the mid-1980s. A variety of regulatory and political factors restrained substantial venture investments by public pension funds until the 1990s (Lerner [1999]).

[35]The effect has been considerable, as public and corporate pension funds currently supply close to 50 percent of all new funds raised by venture capital partnerships (Fenn, Liang, and Prowse [1995]).

[36]National Venture Capital Association Annual Report [1997].

[37]There are two primary reasons why venture funds do not simply take on more partners if they raise additional capital. First, the supply of skilled venture capitalists is quite limited. The effective oversight of young companies requires highly specialized skills that can only be developed with years of experience. A second important factor is the economics of venture partnerships. The typical venture fund receives a substantial share of its compensation from the annual fee, which is typically between 2 and 3 percent of the capital under management. This motivates venture organizations to increase the capital that each partner manages. Recently, several industry leaders have explored mechanisms to facilitate investments by institutions in very small venture funds. These partnerships, they hoped, could readily make small investments in start-up firms. Efforts such as these, however, have encountered considerable difficulties (see Vincenti [1996]).

[38]A growing body of writing suggests that new firms, especially technology-intensive ones, may be receiving insufficient capital. The literature on capital constraints (reviewed in Hubbard [1998]) documents that an inability to obtain external financing limits many forms of business investment. Particularly noteworthy are the limits placed on research and development expenditures, especially in smaller firms.

A related interview theme was the notion that ATP grants help companies take a more "long-term" R&D approach than venture capital financing would permit—an approach characterized by strategic expansions in the scope and depth of R&D projects. As mentioned earlier, many of the pressures that venture capitalists feel to show short-term results comes from the need to raise new funds. Furthermore, because venture capitalists finance companies using a system of staged funding (based on the attainment of short-term milestones), a company needs to show substantial short-term progress if it is to keep receiving capital infusions. As a consequence, venture capital-backed companies may be forced to limit the extent of their R&D activities. For companies that could benefit from a more comprehensive approach to research and development, such a scenario may substantially inhibit growth.

The ATP's system of lump sum grants addresses this issue by combining larger chunks of money with longer time horizons. For early-stage firms, this allows the company's management, rather than an external capital provider, to dictate the direction of R&D projects.[39] "The ATP funds allowed us to take a far more comprehensive R&D approach," said one interviewee. "We were able to shape the process according to the demands of the technology, rather than be a slave to other people's judgment who don't know the field."

In the case of larger companies that have the means to self-fund a substantial portion of their own R&D, several interviewees said that without programs like the ATP their companies would be forced to limit research to projects that have definite near-term commercial payoffs. In this way, ATP grants made it possible for these companies to pursue long-term projects that otherwise would not be undertaken.

The size of ATP grants may also fill in gaps that exist in traditional public and private financing channels. In comparing the ATP to the SBIR program, several interviewees emphasized that in their industries, the Phase I funding ceiling of the SBIR program (originally no more than $50,000; today $100,000 or less) is far too small an initial outlay to be able to show the R&D results necessary for Phase II financing. Similarly, other interviewees stressed that individual investors (commonly referred to as "angels") did not invest enough funds to cover all of their company's basic research and development needs.[40]

Conversely, the size of the typical venture capital investment may be too large for some young, technology-based firms. The average venture capital investment in a start-up company has increased from $1.4 million in 1991 to $3.2 million in 1996.[41] As previously mentioned, the substantial rise in the size of these investments is largely due to increases in fund size driven by the needs of institutional investors. Thus, the size of ATP grants (limited to no more than $2 million for individual projects) helps fill in the substantial gap that exists for companies that need *less* financing than the typical venture capital investment, and *more* capital than is possible from the average individual investor or Phase I SBIR grant.

Last, our research highlighted the ATP's rapid turnaround time as an important program benefit. Several companies said that they were pleasantly surprised at the quick pace of the evaluation process. In this respect, the ATP is in sharp contrast to the staged funding of the SBIR program, in which the turnaround time between Phase I and II financing can be substantial. Because companies have to

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[39]The venture capitalist's staged funding approach, however, frequently improves of the performance of portfolio companies by adding a measure of corporate discipline. Maintaining discipline can be difficult if performance guideposts are placed too far in the future. Furthermore, in industries with short-lived commercialization windows, a long-term R&D focus may be counterproductive. This suggests that a company's ability to benefit from the ATP's long-term approach should perhaps be an explicit consideration when awarding ATP grants.

[40]Freear and Wetzel [1990] report that the median financing round raised by private high-technology firms from individual investors was about $200,000. Furthermore, 82 percent of the rounds from individuals were under $500,000.

[41]National Venture Capital Association [1997].

demonstrate success before moving on to the next phase, time delays are notorious—sometimes forcing companies to put entire research agendas on hold while waiting to see if they will receive additional government financing. In this way, the ATP's more streamlined administrative process reduces the traditional costs of pursuing public funding—thus effectively shaving months off a company's R&D timeline. And in the fast-paced world of new technology markets, a lead time of only a few months can often spell the difference between success and failure.

Areas for Improvement

Although the ATP has helped alleviate imperfections in the financial markets for technology-driven firms, there are several key areas—highlighted both by interviewee comments and our own observations—in which the program could be substantially improved. These areas for improvement fall into two main categories: commercialization policy and company-selection factors. In the section that follows, we examine these issues and draw attention to those program areas that are ripe for reform.

The first category of issues becomes apparent when examining firms that are approaching, or had already reached, the commercialization phase. At the root of these issues is the divergence between a company's agenda and ATP regulations that occurs as the company moves closer to product development. ATP rules stipulate that grants can only fund *pre-commercial* research and development, even though the company is becoming increasingly focused on commercializing the technology. This divergence creates substantial disincentives, especially for the ATP's most successful companies.

For example, if a company completes pre-product R&D ahead of schedule, or is especially efficient in the use of its ATP funds, it is penalized for success. Because it has reached the beginnings of commercialization earlier than expected, ATP rules force the company to decide between either giving up the remaining money, or expanding R&D into non-essential areas.

Both of these options run counter to the objectives of the Advanced Technology Program. The first option—voluntarily giving up the funding—hampers the company's ability to eventually commercialize the technology. Not only is it time-consuming for a business to raise new financing,[42] but once an ATP grant is awarded, the full availability of the funds is often immediately taken into account in financial planning. And because financial planning is especially critical for smaller organizations, losing grant money after it has already been factored into financial decisions could spell disaster for many ATP companies—and, in some cases, leave a company worse off than if the grant had never been awarded in the first place.[43] For these reasons, leaving the funds on the table is an option with extreme costs—especially for small, early-stage businesses.

The second option—expanding pre-product R&D in unnecessary ways—is in direct conflict with the ATP's explicit goal of "accelerating the development process" and "commercializing new scientific discoveries rapidly." As the company expands R&D activities in an effort to fully spend its ATP funding, the company delays its entry into the marketplace. But rapid market entry is critical in the technology-driven industries targeted by the ATP. By delaying entry, the company gives up significant first-mover advantages that could greatly enhance the company's chances of successfully establishing its technology in the market. In addition, there is typically a great deal to be learned from early interactions

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[42]Young, technology-based companies often lack access to substantial bank credit lines. This makes finding alternative sources of capital especially challenging.

[43]The situation may be exacerbated if a venture capitalist is affiliated with a company that loses a government grant. Venture organizations typically invest in planned stages, are adverse to financial surprises in the interim, and allocate just enough capital for a company to reach the next stage. If a company is no longer able to draw upon a government award, it could hamper the company's ability to meet its next milestone, and thus could jeopardize its chances of receiving future venture capital financing.

with customers.[44] Such interactions combat the insulation that frequently occurs when trying to solve real-world problems in a laboratory setting—thereby resulting in an improved product and a faster development cycle. By expanding pre-product research into unnecessary areas, companies may be forgoing the many benefits that accrue from passage along the accelerated learning curves that typically accompany customer interactions.[45]

In the preceding examples, we have seen how the ATP can accelerate the development of a high-risk technology, only to slow down its development just as a funded company is on the verge of success. The issue is further complicated by the typical attributes of the early-stage, technology-driven firms that receive a substantial portion of the ATP's budget. First, a great deal of uncertainty always accompanies these types of firms. Because such companies are in their formative stages and have little or no track record, it is extremely difficult for their managers to predict the optimal magnitude and duration of R&D expenditures at the onset of a project. Regardless of the time and energy devoted to such forecasts, it is likely that initial estimates will have to be revised over time. The uncertainty surrounding early-stage, high-tech firms highlights the need for considerable flexibility in the application of ATP funding regulations.

Second, the typical ATP company is very susceptible to changing market conditions. Because high-technology is an extremely fast-paced segment of the market, during the course of a two- or three-year project, windows of opportunity for ATP companies can change dramatically. As a result, project managers often need to revise and refocus their plans.

ATP regulations do not allow for these types of adjustments. "If market conditions change and a company wants to adapt," said one interviewee. "a lot of friction exists with trying to modify the existing contract to reflect those new conditions." According to another interview participant, flexibility existed only as long as the procedure, but not the direction, of the project changed. To better tailor ATP regulations to business considerations, greater flexibility is needed to allow companies to adjust their R&D plans in accordance with changes that they see in the marketplace. Just because a company is pre-competitive doesn't mean that it is immune from market dynamics, or that generic approaches toward funding it will work.

Third, it is difficult for these companies to truly solve research problems without beginning some type of product formulation. "We tried to delineate between R&D and commercialization, but it proved to be difficult," said one interviewee. "You can't really be solving research problems without some development of the product." While larger companies can fund product development activities with other resources, smaller companies do not usually have this luxury. Furthermore, several companies in our sample found it difficult to even distinguish between pre-product R&D and early commercialization. "We came to feel that there was substantial risk involved in making this distinction between R&D and commercialization," one interviewee commented.

For all of the reasons mentioned above, malleable R&D blueprints are critical for young, technology-based firms. Although current ATP regulations may be appropriate for firms that continue to struggle with pre-product R&D challenges, for the ATP's most successful firms, rigid regulations against any form of product development impede their progress.

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[44]The work of Eric von Hippel [1988], for instance, illustrates how end users can have a major impact on product innovation. He shows that in some fields (such as semiconductor processing equipment) the innovation users—not the product manufacturers—actually develop most innovations.

[45]Furthermore, if a venture capitalist is also providing capital to the company, a tension is created between ATP monitoring (which limits the pace of commercialization), and venture capital monitoring (which drives the company toward product development).

To address this problem, our interviews suggest that the ATP should permit greater flexibility in the application and enforcement of its commercialization rules. One possible solution is a rolling research agenda, in which other projects could be dropped in as substitutes for projects that are approaching the commercialization stage. Another possible reform would be to offer more project leeway as a reward for performance, if a company can demonstrate that it has already achieved its research goals, and is, in fact, ready to make a transition toward commercialization. This leeway, of course, could be extended only in very specific instances, and need not be a publicized portion of the program. And as is the case with current ATP rules, program monitoring would prevent potential abuses of the modified guidelines. "In an effort to watch dimes, you sometimes lose sight of the big picture," said one interviewee. "The increased tax revenues alone would likely make up for the costs."

Although added flexibility in commercialization regulations could improve the dynamic between the ATP and its most successful companies, other reforms are needed to weed out a greater number of underachieving firms. In particular, certain company characteristics—attributes that may not be adequately considered in the ATP selection process—appear to be highly correlated with a company's ability to achieve its research and commercialization goals. By devising new methods to search for such factors, the ATP would be better able to distinguish between high-performing and underachieving firms.

Our research indicates that a prevalent characteristic among underachieving companies is the existence of research grants from numerous government sources, with few, if any, tangible results to show for these R&D dollars. Because a lack of results can easily be attributed to the high-risk nature of technology development, many of these companies can avoid accountability indefinitely. As a result, these government grant-oriented research organizations are able to drift from one Federal contract to the next. For such companies, it appeared that ATP funds were treated in exactly the same manner as other government research grants: It did not appear that ATP funding showed any notable returns or that the ATP's unique program goals were particularly well-served.

Adding to the problem is the fact that companies with substantial government grant experience appear to have several advantages over other firms when applying for future public awards. Past grants, regardless of project outcomes, help a company gain legitimacy in a particular area of research, as well as acquire the equipment and personnel needed to do future work. There is also a tendency for some government programs to try to "piggyback" on other government programs, hoping to leverage their grant dollars. In addition, firms gain considerable insight on the grant application process with each proposal they submit. Because of all of these factors, these firms frequently have a greater chance of being awarded future government grants than other firms. The end result can be a stream of government funding being awarded to companies that consistently underachieve.

Furthermore, there appears to be special advantages for past ATP winners when applying for future ATP awards. The companies in our sample indicated that after submitting multiple ATP proposals and completing an ATP project, they gained a significantly better understanding of how to appeal to the ATP's unique selection criteria. In fact, one interviewee frequently advises first-time applicants on how to write and structure ATP proposals. In addition, past ATP award recipients may develop relationships with ATP evaluators and managers that aid in the selection process.

To level the playing field, our research suggests that the ATP should more closely scrutinize the amount of funding a company has received from prior government sources. A greater number of underachieving firms could be weeded out if the ATP conducted a more comprehensive evaluation of a company's past performance and examined the tangible progress attributable to each government grant the firm has received. Moreover, large inflows of prior government funding without significant product development may indicate that a particular company does not fit the ATP's commercialization objectives. It is unlikely that ATP goals will consistently be met by funding these types of companies.

Another telltale characteristic of underachieving firms was the existence of factors outside the scope of ATP projects that undermined their ability to successfully complete and later commercialize ATP-funded technology. Legal troubles, for instance, can divert substantial amounts of human and financial resources away from a company's R&D projects. For early-stage firms, legal problems may even cause dramatic changes in the size and structure of the company. And when a firm is ready to commercialize its technology, the liability concerns associated with pending legal battles will often drastically impair the company's ability to attract venture capital investment dollars.

The existence of resource-draining auxiliary research projects can also potentially undermine a company's performance. One company in our sample, for instance, was involved in a project that was only distantly related to the company's core (and ATP-funded) technology. Although the ATP grant was not used to fund this auxiliary project, it appeared that a substantial amount of the company's time, energy, and capital was diverted toward this tangential research. This, in turn, diluted the company's focus on its ATP-funded research project, and thus slowed down the development of its core technology.[46] The existence of unrelated R&D projects, especially for smaller companies, can cause a company's resources to be spread too thin.

For early-stage companies, additional limiting factors frequently involve managers who lack experience in running small companies. Although some of these managers may have accumulated business experience as consultants or as members of large organizations, the successful operation of early-stage companies can demand very different management skills. It thus comes as no surprise that when venture capitalists sink substantial funds in a company, they will often place their own hand-picked manager in charge—typically an individual who has already been successful in managing an early-stage company in a similar industry. Because much of the skills needed for managing start-up companies comes through experience, the existence of managers who do not have this background can significantly undermine a company's ability to carry out its commercialization plans.

In a broader context, each of these performance-undermining factors emphasizes the need for the ATP to critically evaluate whether a particular company is a viable vehicle for accomplishing its commercialization goals. This goes far beyond a simple assessment of the feasibility of a business plan. In fact, many of these potentially limiting factors will not even be discussed in a company's written ATP proposal. It is tempting, of course, to attribute the failures resulting from such factors to the high-risk nature of the technology. But to a large extent, companies exhibiting a high potential for underachievement could be more thoroughly weeded out by placing a greater emphasis on these factors during the selection process. The R&D project itself may be high-risk, but the risks of turning the technology into a product should be minimized. Regardless of how innovative or enabling a technology may be, or how well a business plan is constructed, if these undermining factors are substantial, a company will be hard pressed to overcome such roadblocks.

Issues for Further Examination

The interviews also highlighted three key areas for further study: (1) the quality of ATP due diligence, (2) the ability of the ATP to "signal" promising technologies, and (3) the effects of industry targeting. Although our interview sample was not large enough to reach definitive conclusions on these issues, our research suggested future avenues for further analysis.

[46]Part of the problem in this instance is the lack of corporate discipline. If a venture capital firm had invested in this company, it likely would have provided this discipline by closely monitoring the company, and limiting the company's R&D activities to areas that were directly related to its core technology.

(1) The Quality of ATP Due Diligence

The companies in our sample that had received grants from other government programs were in agreement that the ATP's evaluation process was at least as thorough, and often more comprehensive, than its counterparts among other Federal programs. Furthermore, interviewees reported that the added speed at which the ATP made decisions and appropriated funds (in comparison to the SBIR program in particular) did not appear to negatively impact the quality of the due diligence.

When comparing ATP due diligence to that of the private sector, however, companies in our sample considered the venture capitalists to be substantially more thorough in evaluating companies.[47] But the extent of the perceived due diligence quality gap tended to vary from industry to industry. According to one interviewee, "The ATP was very diligent about the business side of things. I was very impressed with the level of evaluation." But according to another, "ATP due diligence is nothing like a VC review where they have to carefully consider the return. While the VC firm sent in teams of specialists, no one from the ATP even came to see if we actually had a lab—let alone to see if the people in the lab coats were actors." In general, there appeared to be a greater parity between ATP and venture capital due diligence in industries where on-site visits were less critical and where venture capitalists were not as well versed. Future studies could examine the quality of ATP due diligence on an industry-specific basis.

(2) "Signaling" Promising Technologies.

In assessing the impact of the Advanced Technology Program, an important issue is whether the ATP stamp of approval "signals" promising technologies to other capital providers. If signaling does occur, then a company should find it easier to obtain capital from other sources after being awarded an ATP grant. In our interview sample, the strongest signaling effects were, in fact, to other government grant programs. Several companies indicated that ATP funding helped certify the quality of their technology to such programs. Furthermore, one interviewee said that these programs were especially interested in funding extensions of ATP-sponsored research because their grants would be building upon prior work financed by another program's budget.[48]

The interviews also shed light on potential signaling effects to private equity investors. There appeared to be a link between the experience of venture capitalists in a particular industry and the extent to which it was believed that the ATP added signaling value. According to companies in industries that are less familiar to venture organizations, the ATP grant served as a good signal, helping to attract outside investors. On the contrary, in industries frequently funded by venture capitalists, the companies believed that the ATP added little signaling value. Of course, a much larger sample of companies is needed to determine if such observations are part of a larger trend. Such preliminary results do suggest, however, that it would be worthwhile to study how stronger links could be built with the venture capital community. This is especially true given the success of venture-backed firms.

(3) The Effects of Industry Targeting.

An issue raised by several companies in our sample concerned how the ATP explicitly targets—through focused program competitions—technologies that are deemed critical to the national interest.[49] Although no company voiced dissatisfaction with such strategies in principal, more controversy existed when it came to the question of *which* industries should be targeted.

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[47]This should not necessarily be viewed as a negative program attribute, given that the ATP has significantly fewer resources to devote to the due diligence process at its disposal.

[48]In one instance, a government program's technical evaluation explicitly stated that funding a particular project would be especially advantageous given that it "would leverage on the ATP program...."

[49]From 1994 to 1998, the ATP devoted the bulk of its funding to focused program areas—multiyear efforts of approximately $20 million to $50 million per year.

Factoring into the equation is the reality that venture investments tend to be highly concentrated by industry: In 1996, for example, the "communications and networking" and "software and information services" industries alone accounted for nearly half of all dollars invested by venture capitalists.[50] Because of such concentration, one concern in particular raised by interviewees was that the ATP may be tempted to select "hot" industries—ones already saturated with venture capital funding—in order to demonstrate the immediate relevance and worth of the program to Congress and others. "When the ATP does this," one interviewee said, "it seems like a lot of deserving technologies are passed over for industries that don't need the funds as much."

If the ATP is indeed targeting industries that are well funded by the private sector, then the government is caught in a no win situation. If the government lags behind venture capitalists and is the last party to show up on the scene, it is likely that the best prospects will have already received funding. In such a scenario, the potential return on each government dollar may be severely limited. On the other hand, if the government can find the best prospects in an industry first, leaving the private sector stuck with a pool of less desirable companies, it is likely that the government is counter-productively "crowding out" private investment.

The outcome may be more positive, however, if the government funds a promising industry that the private sector has overlooked (perhaps because it is too high risk), partners with venture capitalists to accelerate R&D cycles in an industry, or signals new industries in which venture capitalists and others will subsequently invest. In essence, only when the government can isolate promising yet under-funded industries (or segments of industries)[51] does it add substantial value through industry targeting. In this scenario, ATP can be viewed as "pre-seed" capital, providing funds to companies that ultimately will be "handed off" to professional venture capitalists. An empirical and qualitative analysis of the characteristics of such industries, and the ATP's track record in locating them, is potentially a fruitful area for future study.

Conclusions

Since its inception in 1990, the Advanced Technology Program has awarded nearly one billion dollars in research and development funding to approximately 300 technology-based projects conducted by American companies and industry-led joint ventures. Based upon interviews with a diverse group of seven ATP-funded companies, it is our belief that the ATP does, in fact, substantially expand and enhance the R&D activities of the firms it funds.

Our research further indicates that the ATP's impact is especially potent on small, early-stage firms. The ATP helps incubate young companies by providing them with the capital to develop technology, construct prototypes, and thus demonstrate the value of their ideas to potential investors. From 1990 to 1997, 36 percent of ATP funding has gone to small businesses, with an additional 10 percent going to joint ventures led by small businesses. The ATP's potent effect on such firms suggests that perhaps an even larger portion of ATP funds should be allocated to small, early-stage companies in the future.

The interviews also showed how ATP grants make it possible for companies to expand the scope and depth of R&D projects in accordance with long-term considerations. For smaller companies, ATP funding provides the company's management with control over the direction of R&D projects. This control might be lost if they raised money from an external capital provider. For larger companies with

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[50]National Venture Capital Association [1997].

[51]Our earlier analysis indicated that early-stage firms that need relatively small capital infusions (regardless of industry) might be a segment under-funded by venture capitalists. Additional analysis could examine whether this financing gap is driven by specific industries.

limited research budgets, ATP grants provide the means to pursue long-term projects that otherwise would not be undertaken.

Other notable strengths of the Advanced Technology Program include the size of ATP grants and the program's rapid turnaround time. The size of ATP grants helps fill the financing gap for companies which need *less* financing than the typical venture capital investment and *more* capital than is possible from the average angel investor or Phase I SBIR grant. The ATP's rapid turnaround time reduces delay, and thus speeds up the development cycle, lessening one of the traditional costs of pursuing government financing.

Although our research highlighted several benefits of the Advanced Technology Program, the interview process also uncovered some important areas for potential program reforms. One such area involved the disincentives that ATP funding regulations can create as a company's technology approaches the commercialization phase. Because ATP rules stipulate, without exception, that grants can only fund pre-product research and development, the company's agenda and ATP regulations are at odds with one another during this transitional period. This situation can slow down the development process and hamper the company's ability to eventually commercialize the technology. This is an especially troubling scenario given that the ATP's most successful firms are the ones who suffer the greatest penalty. Such commercialization issues make a strong case for greater flexibility in the application and enforcement of ATP funding regulations.

Our interviews also isolated potential reforms that could weed out a greater number of underachieving firms. Chief among such underachievers are companies that accumulate substantial amounts of government grants, have a "contract research" mentality, and stay in business largely on the basis of these awards. Such companies can avoid accountability indefinitely and over time can become experts in the grant application process. Our research suggests that a greater number of such firms could be weeded out through a more comprehensive evaluation of past results. Perhaps the number of government grants a company has received (compared to the number of products it has developed) should be a specific litmus test employed in the ATP selection process.

In a broader sense, our research suggests that the ATP should place a greater emphasis in its selection criteria on whether a company is a viable vehicle for actually accomplishing its commercialization goals. Regardless of the quality of a particular technology or business plan, if substantial undermining factors exist—such as legal troubles, distracting auxiliary projects, or managers inexperienced in running early-stage firms—a company's technology will be hard pressed to reach commercial fruition.

Our research also identified three important areas for further study. We first posed the question of how ATP due diligence compares to the due diligence conducted by other government programs as well as by venture capitalists. The companies in our sample were in agreement that the ATP's evaluation process was at least as thorough, and often more comprehensive, than its public counterparts. In comparison to the private sector, however, venture capitalists were considered substantially better at due diligence. But the extent of this quality gap between venture capital due diligence and ATP due diligence varied from industry to industry.

Second, we assessed the ATP's potential to signal promising technologies to other capital providers. Interestingly enough, the strongest signaling effects we found were to other government programs. In our sample, signaling effects to private equity investors appeared to be limited to companies in industries with less of a venture capital influence. Third, several companies raised the issue of industry targeting. One concern in particular was that the ATP may target, or have incentives to target, industries already saturated with venture capital. This would be to the detriment of more cash-starved industries.

Although this project was based upon case interviews with a relatively small number of ATP-funded companies, our research highlighted issues that have implications for the Advanced Technology Program as a whole. A fertile area for further qualitative analysis could involve a series of interviews with venture capitalists that both are and are not affiliated with ATP-funded companies. Such a project would bring an alternate perspective to many of the issues discussed in this paper and would shed greater light on potential ways for the ATP and the venture capital community to better work together as partners in technology cultivation.

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Chapter 4

Research Studies On Venture Capital

A. What Drives Venture Capital Fundraising?[52]

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We examine the determinants of venture capital fundraising in the U.S. over the past twenty-five years. We study industry aggregate, state-level, and firm-specific fundraising to determine if macroeconomic, regulatory, or performance factors affect venture capital activity. We find that shifts in demand for venture capital appear to have a positive and important impact on commitments to new venture capital funds. Commitments by taxable and tax-exempt investors seem equally sensitive to changes in capital gains tax rates, consistent with the notion that decreases in capital gains tax rates increase the demand for venture capital as more workers are incented to become entrepreneurs. Aggregate and state level venture fundraising are positively affected by easing of pension investment restrictions as well as industrial and academic R&D expenditures. Fund performance and reputation also lead to greater fundraising by venture organizations.

1. Introduction

During the past twenty years, commitments to the U.S. venture capital industry have grown dramatically. This growth has not been uniform: it has occurred in quite concentrated areas of the country and peaks in fundraising have been followed by major retrenchments. Despite the importance of the venture capital sector in generating innovation and new jobs, few academic studies have attempted to determine the underlying causes of these dramatic movements in venture fundraising.

In this paper we examine the forces that affect fundraising by independent venture capital organizations from 1972 through 1994. We study both industry fundraising patterns and the fundraising success of individual venture organizations. We find that regulatory changes affecting pension funds, capital gains tax rates, overall economic growth, and research and development expenditures—as well as firm-specific performance and reputation—affect fundraising by venture capital organizations. The results are potentially important for understanding and promoting venture capital investment.

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Various factors may affect the level of commitments to venture capital organizations. Poterba (1989) argues that many of the changes in fundraising could arise from changes in either the supply of or the demand for venture capital. When we refer to the supply of venture capital, we mean the desire of investors to place money into venture capital funds. Demand is then the desire of entrepreneurs to attract venture capital investment in their firm. For example, decreases in capital gains tax rates might increase commitments to venture capital funds through increases in the desire of taxable investors to make new commitments to funds as well as through increases in the demand for venture capital investments when workers have greater incentives to become entrepreneurs. Our research methodology attempts to distinguish between supply and demand factors that affect the quantity of venture capital.

We find that demand-side factors appear to have had an important impact on commitments to venture capital funds. Capital gains tax rates have an important effect at both the industry, state-, and firm-specific levels. Decreases in the capital gains tax rates are associated with greater venture capital commitments. The effect, however, appears to occur through the demand for venture capital: rate changes affect both taxable and tax-exempt investors. Similarly, R&D expenditures, especially expenditures by industrial firms, are positively related to venture investments in particular states.

We also find that The Department of Labor's clarification of its "prudent man" rule, which enabled pension funds to freely invest in venture capital, and individual venture firm performance and reputation influence fundraising. Higher recent returns (as measured by the value of equity held in firms taken public) lead to greater capital commitments to new funds. Older and larger organizations also attract more capital. Finally, we examine factors that affect venture organizations' decisions to raise funds targeted at early-stage, start-up firms. These funds are potentially the most important for generating new firms and innovation. We find that smaller, West Coast venture organizations are more likely to have raised an early-stage venture fund.

The rest of the paper is organized as follows: A brief discussion of the institutional details of venture capital is presented in Section 2. Section 3 discusses the economics of venture capital and presents factors that might affect venture capital fundraising. Industry-wide fundraising patterns, at both the aggregate and state level, are explored in Section 4. Section 5 explores fundraising by individual venture organizations in an exhaustive database of venture capital funds. Section 6 considers alternative explanations. Section 7 concludes.

2. The Institution of Venture Capital[53]

In this section we briefly review the institutional details of venture capital organizations. The discussion highlights the structure and function of venture capital organizations in the U.S. and how venture capital is distinct from other sources of financing for young, entrepreneurial companies. In addition, we seek to place the development of the venture capital industry in context so the tests discussed in Section 3 are better understood.

Many start-up firms require substantial capital. A firm's founder may not have sufficient funds to finance these projects alone and might therefore seek outside financing. Entrepreneurial firms that are characterized by significant intangible assets, expect years of negative earnings, and have uncertain prospects are unlikely to receive bank loans or other debt financing. For many of these young companies, the tremendous uncertainty and asymmetric information may make venture capital the only potential source of financing. Venture capital organizations finance these high-risk, potentially high-reward projects, purchasing equity stakes while the firms are still privately held. Venture capitalists have backed many high-technology companies including Apple Computer, Cisco Systems, Genentech, Intel,

[53]Much of this discussion is based on Gompers and Lerner (1996).

Microsoft, Netscape, and Sun Microsystems. A substantial number of successful service firms (including Federal Express, Staples, Starbucks, and TCBY) have also received venture financing.

Venture capitalists are often active investors, monitoring the progress of firms, sitting on boards of directors, and meting out financing based on the attainment of milestones. While banks monitor the financial health of firms that they lend to, venture capitalists monitor strategy and investment decisions as well as take an active role in advising the firm. Venture capitalists often retain important control rights that allow them to intervene in the company's operations when necessary. In addition, venture capitalists provide entrepreneurs with access to consultants, investment bankers, and lawyers. Brav and Gompers (1997) show that venture capital backing adds value even after the initial public offering: venture-backed companies substantially outperform nonventure-backed firms in the public aftermarket.

The first modern venture capital firm, American Research and Development (ARD), was formed in 1946 by MIT President Karl Compton, Harvard Business School Professor Georges F. Doriot, and local business leaders. A small group of venture capitalists made high-risk investments into emerging companies that were based on technology developed for World War II. The success of the investments ranged widely: almost half of ARD's profits during its 26-year existence as an independent entity came from its $70,000 investment in Digital Equipment Company (DEC) in 1957, which grew in value to $355 million. Because institutional investors were reluctant to invest, ARD was structured as a publicly traded closed-end fund and marketed mostly to individuals [Liles (1977)]. The few other venture organizations begun in the decade after ARD's formation were also structured as closed-end funds.

The first venture capital limited partnership, Draper, Gaither, and Anderson, was formed in 1958. Imitators soon followed, but limited partnerships accounted for a minority of the venture pool during the 1960s and 1970s. Most venture organizations raised money either through closed-end funds or small business investment companies (SBICs), federally guaranteed risk-capital pools that proliferated during the 1960s. While the market for SBICs in the late 1960s and early 1970s was strong, incentive problems ultimately led to the collapse of the sector. Even so, the annual flow of money into venture capital during its first three decades never exceeded a few hundred million dollars and usually was substantially less.

One change in the venture capital industry during the past twenty years has been the rise of the limited partnership as the dominant organizational form.[54] Limited partnerships also have an important advantage which makes them attractive to tax-exempt institutional investors: capital gains taxes are not paid by the limited partnership. Instead taxes are paid only by the (taxable) investors. Venture partnerships have pre-determined, finite lifetimes (usually ten years though extensions are often allowed). Investors in the fund are limited partners. In order to maintain limited liability, investors must not become involved in the day-to-day management of the fund.

3. The Economics of Venture Capital

3.1 Supply and demand in venture capital

In this section we develop predictions about what factors might influence the quantity of venture capital provided in an economy. In order to understand the mechanism through which these factors work, it is important to discuss supply and demand in the venture capital market. Figure 1 presents a simple illustration of equilibrium in the venture capital market. Supply of venture capital is determined by the willingness of investors to provide funds to venture firms. The willingness of investors to commit money to venture capital is dependent upon the expected rate of return on venture investments. Therefore, in the

[54]The rise of the limited partnership also allows us to accurately track venture capital fundraising. Venture capital limited partnerships raise a pre-specified amount of money to be invested. The data discussed in Section 5 is fund-by-fund tracking of these amounts.

venture capital market, price is the expected rate of return on new venture capital investments. Higher expected returns lead to a greater desire of investors to supply venture capital, *i.e.*, like most supply schedules it slopes upward.

The demand schedule is simply the quantity of entrepreneurial firms seeking venture capital that can supply a particular expected rate of return. As the price increases—the expected return increases—fewer entrepreneurial firms demand capital because the quantity of projects meeting that threshold declines. The demand schedule therefore slopes downward.

We will discuss the equilibria in the supply and demand framework by examining the quantity of venture capital. While any supply and demand equilibrium also implies a particular price, *i.e.*, an expected rate of return, we can not measure the anticipated rate of return in the venture capital market. Nor does the actual rate of return provide a useful proxy. Returns from venture capital investments can only be observed many years after the original investments because private firms are valued at cost until they are sold or taken public many years later. Because of these accounting policies, the stated returns for venture funds are exceedingly variable and somewhat misleading. [See the discussion in Gompers and Lerner (1997).][55] We feel fairly comfortable that the expected rate of return, *i.e.*, price, will not vary substantially across the sample period. As discussed below, however, supply curves for venture capital are likely to be very elastic. Hence, changes in equilibrium will have a significantly larger effect on quantities than on prices.

The supply schedule for venture capital is likely to be quite flat. Investors choose to place money in financial assets because of the monetary returns that they return. Because close substitutes for these cash flows exist either through a single security or combination of securities, investors will have a particular expected return on venture capital that just compensates for the systematic riskiness of the investments [Scholes (1972)]. If perfect substitutes for venture capital existed, then the supply curve should be totally flat. We draw supply curves as slightly upward sloping in Figure 1. One source of an upward slope would be differential taxes. Because the return on venture capital investments is taxable, investors with higher tax rates would require progressively higher expected rates of return to induce them to invest in venture funds versus some tax-free investment.

3.2. The Employment Retirement Income Security Act and venture commitments

One policy decision that potentially had an effect on commitments to venture funds via supply changes is the clarification by the U.S. Department of Labor of the Employment Retirement Income Security Act's (ERISA) prudent man rule in 1979. Through 1978, the rule stated that pension managers had to invest with the care of a "prudent man." Consequently, many pension funds avoided investing in venture capital entirely: it was felt that a fund's investment in a start-up could be seen as imprudent. In early 1979, the Department of Labor ruled that portfolio diversification was a consideration in determining the prudence of an individual investment. Thus, the ruling implied that an allocation of a small fraction of a portfolio to venture capital funds would not be seen as imprudent. That clarification specifically opened the door for pension funds to invest in venture capital.

We conjecture that the supply curve for venture capital before the clarification of ERISA might have looked like S_1. The upward inelastic segment of S_1 results because pension funds, a segment of the U.S. financial market that controls substantial amounts of capital, were unable to invest in venture funds. The supply of venture capital may have been limited at any expected rate of return. If the initial demand for venture capital were given by D_1, then the equilibrium quantity of venture capital would be given by Q_1.

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[55]In addition, practices of reporting valuations of companies across various venture organizations is often quite different. Finally, information on fund returns is closely guarded, and even the intermediaries who specialize in compiling this data do not have very comprehensive coverage.

After ERISA, the supply curve moved to S_2. The supply curve moved down and flattened out. The supply curve moved down because pension funds, which are tax exempt, required a lower expected rate of return on venture investments than other taxable investors. The curve would not have an inelastic segment because the resources of pensions could now be invested in venture capital funds. When we look at the data, we expect that the quantity of venture capital supplied will increase after ERISA was clarified to Q_2. This effect should only be significant for contributions by pension funds because ERISA regulations have no bearing on other types of investors.

3.3. Capital gains taxes and venture capital fundraising

The effect of capital gains tax rates on commitments to the venture capital industry has been debated in the academic literature as well as political circles. The effect of reductions in the capital gains tax rate on commitments to venture capital was one of the intended benefits of the reduction of the tax from 28% to 14% on investments in small companies held for five years that was enacted in 1993.

Poterba (1989) argued that it was unlikely that capital gains taxes affected venture capital by shifting the supply curve. The supply effect of capital gains tax reductions is illustrated by C in Figure 1. A reduction in the capital gains tax rate would lower the required expected (pre-tax) rate of return on venture investments for taxable investors. This would cause the right-hand side of supply curve S_2 to shift down to S_3. Most investors in venture capital after 1980 have been tax-exempt institutions and the supply effect may therefore have been small.

Poterba then develops a model of the decision to become an entrepreneur. He argues that the capital gains tax rate could have a dramatic effect on this choice. Lower capital gains tax rates make it relatively more attractive for a manager or worker to start his or her own company. Most of a manager's compensation comes in the form of salary and cash bonuses which are taxed at the ordinary income tax rate. Most of the compensation from being an entrepreneur is in the form of capital appreciation on the equity of the company. Poterba argues that it is possible that reductions in the capital gains tax rates could have a first-order effect on the demand for venture capital as more people are induced to become entrepreneurs and better projects are brought to market. This would increase the quantity of venture capital demanded to D_2 and increase the equilibrium quantity of venture capital to Q_3.[56]

If the capital gains tax rate has an important impact on commitments to venture capital funds, then we would expect a significant relation at the industry level and at the fund-specific level. Lower capital gains taxes should lead to increases in commitments to the industry as a whole as well as to individual funds. We can also shed light on whether Poterba's argument about supply and demand effects is valid. If capital gains taxes affect commitments to venture capital primarily through the demand for venture capital, then we expect that reductions in the capital gains tax rate should have a positive impact on the commitments of both tax-exempt and tax-sensitive investors. If the effect is primarily due to supply changes, then contributions by tax-exempt investors should be unrelated to the capital gains tax rate. Because we can separate contributions to venture funds by investor type, we should be able to determine whether the demand effects (B in Figure 1) or supply effects (C in Figure 1) of decreases in the capital gains tax rate are more important.

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[56] Anand (1996) examines the effects of capital gains tax rates on investment in the communications industry. He examines investments by venture capital firms into private communication companies and finds that the level and composition of investment appears to be affected negatively by increases in the capital gains tax rate. The author's ability to draw conclusions, however, is limited by the fact that he looks only at one industry. Investments in one industry may be affected by myriad other factors, including technology shifts, tastes, or other investment opportunities. Examining the impact of capital gains tax rates on the quantity of venture capital raised appears to be a much more satisfactory way to address the issue.

3.4. Other macroeconomic factors and venture fundraising

Venture capital fundraising is potentially affected by other macroeconomic factors as well. Commitments could be affected by both the expected return on alternative investments and the general health of the economy. If the economy is growing quickly, then there may be more attractive opportunities for entrepreneurs to start new firms and, hence, increases in the demand for venture capitalists. Formally, the demand curve would shift to the right. The greater investment opportunity set might be associated with greater commitments to the venture capital industry. GDP growth, returns in the stock market, and R&D expenditures would all be potential proxies for demand conditions.

The level of interest rates in the economy also could affect the supply of venture capital. An alternative investment to venture capital is bonds. If interest rates rise, then the attractiveness of investing in venture capital funds may decline. This would decrease the willingness of investors to supply venture capital at all prices, *i.e.*, at all expected return levels.

3.5. Firm performance and fundraising

In this section we develop hypotheses about factors that might affect venture capital fundraising at the firm level. In addition to the market-wide factors discussed above, we look for venture capital firm-specific characteristics that may influence fundraising. First, a substantial body of research examines the relation between past performance and investment. Allocations by investors across asset classes seem to be driven by, in part, the relative performance of various sectors over the recent past. If there is short-run momentum in returns—as shown by Grinblatt, Titman, and Wermers (1995)—this response may be rational.

The flow of money into and out of various types of financial institutions in response to performance has been documented extensively of mutual funds. While the early research on mutual funds [Jensen (1968); Ippolito (1989)] indicated that mutual fund managers as a group do not significantly outperform the market, recent work has shown cash flows appear to respond to past performance. Sirri and Tufano (1998) find that performance relative to peers in the same investment category is an important determinant of new capital commitments to mutual funds. They examine 690 equity mutual funds and rank the funds by their performance relative to funds that have the same investment focus. They find that the top performing funds in any particular investment style have substantial new commitments to their funds in the subsequent year. The relation between performance and commitments, however, is not linear. Funds that perform poorly do not appear to be penalized in the following year. Money does not leave poor performing funds. Sirri and Tufano (1998) find that one exception to these findings is new funds. Money does seem to leave a new fund if it is a poor performer.

Chevalier and Ellison (1997) examine how these patterns affect investment incentive functions. They find that funds which have underperformed their peers in the first part of the year have an incentive to increase the riskiness of their portfolios in order to increase the chances that they will end up near the top of the performance charts. If they bet wrong and fail, they will lose few of their current investors.

If the evidence from mutual funds has implications for venture capital, then we would expect that recent performance would be positively related to commitments to new funds. As in Sirri and Tufano's (1998) mutual fund results, reputation of the venture organization may influence the flow of new commitments when it raises a new fund. Several measures of reputation may be important. These include venture organization age and capital under management. Older and larger venture organizations are likely to have more established reputations. They may therefore receive larger capital commitments than similar younger funds.

4. Venture Industry-Wide Results

We examine the implications of performance and capital gains tax rates for commitments to venture capital funds by performing two layers of analysis: aggregate flows and commitments to individual funds. The first level of analysis examines the flow of venture capital commitments into the industry. We examine the commitments to new venture capital funds from 1969 through 1994 first aggregating all commitments in the U.S. We then take up an analysis of the level of venture activity on a state-by-state basis.

4.1. Aggregate fundraising results

Data on annual commitments to U.S. venture capital funds come from the consulting firm Venture Economics. This organization has tracked venture fundraising since the 1960s. This database not only records venture capital organizations, but also the names of their individual funds. We have checked the entries in this database against the historical information reported in over 400 venture offering memorandums and partnership agreements, as well as against the fund profiles in the *Venture Capital Journal* and *Private Equity Analyst*. [The construction and verification of the database are described in Gompers and Lerner (1998a).] This database is also used in the analysis of individual organizations' fundraising data analyzed in Section 5.

This database includes over two thousand venture capital funds, SBICs, and related organizations. It is used in preparation of directories such as their annual volume *Venture Capital Performance*. It is compiled from information provided by venture capitalists and institutional investors. In examining fundraising behavior, we only look at venture capital limited partnerships. First, these partnerships are the dominant organizational form in the industry, accounting for roughly 80% of commitments to the venture capital industry in recent years. Furthermore, the actual size of SBICs and corporate venture affiliates is often very difficult the estimate. SBICs have access to matching government funds, often several times greater than the amount contributed by private investors. Corporate programs usually do not have a pool of capital specified in advance and are frequently disbanded before being investing much capital. Limited partnerships—with their well-defined size and life-span—offer the cleanest estimate of venture capital inflows.

We total commitments to venture funds each year. Commitments are defined as the pledges that venture capitalists receive for investment over the lifetime of the fund. They are not the amount of money that is actually invested in a given year. Typically, venture funds draw on and invest the committed capital over a two to three year time period. For example, in 1995 Sierra Ventures raised their fifth fund with aggregate commitments of $100 million. This $100 million would be invested between 1995 and about 1999, but we would classify the entire $100 million as having been committed in 1995.

We also need some measure of returns in the venture capital industry. Ideally, we would have year-by-year performance data for individual funds. These data present several problems. As discussed above, calculation of returns is hampered by policies of many venture organizations that potentially delay the write-up or write-down of assets. As a proxy for performance of the venture organizations, we use a measure of the market value of equity held by venture capitalists in firms that went public in a particular year. This measure will be highly correlated with returns on venture funds. Most money in venture capital is earned on firms that eventually go public. Ignoring the companies that do not go public is reasonable because their impact on returns is usually quite small. A Venture Economics study (1988) finds that a $1 investment in a firm that goes public provides an average cash return of $1.95 in excess of the initial investment with an average holding period of 4.2 years. The next best alternative, an investment in an acquired firm, yields a cash return of only 40 cents over a 3.7 year mean holding period. Using the IPO measure also makes sense because marketing documents for venture capital funds often highlight the successful public companies which have been backed by the venture organization. We

therefore expect that the amount of venture capital raised will be a positive function of the value of firms taken public by venture capitalists in the previous year.

We identify potential venture-backed IPOs using three sources. The first is the listings of venture-backed IPOs published in Venture Economics' *Venture Capital Journal*. This is the same source used by Barry, *et al.* (1990) and Megginson and Weiss (1991). We also use listings of the securities distributions by venture funds. Venture capitalists typically unwind their successful investments by distributing the shares to their limited partners. They avoid selling the shares themselves and distributing the proceeds to their limited partners because their investors include both tax-exempt and tax-paying parties. To sell the shares would generate an immediate tax liability, which some of the limited partners may wish to avoid. We obtain lists of the distributions received by a pension fund which is among the largest venture investors and by three investment managers [Gompers and Lerner (1998b)]. (These investment managers allocate funds from numerous pension funds into venture capital and other asset classes.) These investors had received distributions from 135 venture funds, most of which are managed by the oldest and most established venture organizations in the industry. Most of the successful investments by these funds can be identified from these lists.

The final source used to identify IPOs for the sample are the offering documents used by venture capitalists to raise new funds from investors. Venture organizations will often list in these offering memorandums their past investments that either went public or were acquired on favorable terms. We examine over four hundred of these memorandums in the files of Venture Economics [Gompers and Lerner (1998a)]. We identify any investments listed as having gone public. Most of the offering documents compiled by Venture Economics are from young venture organizations. This is because their Fund Raiser Advisory Service counsels less experienced firms on strategies for raising capital.

We include in the IPO sample all firms if a venture investor listed in the "Management" and "Principal and Selling Shareholders" sections of the IPO prospectus is listed in the Venture Economics database. In many cases, it is not immediately obvious whether a venture investor or director is an exact match with a venture organization listed in the database.[57] To address these ambiguities, we consult the edition of Venture Economics' *Pratt's Guide to Venture Capital Sources* (1996) published in the year of the IPO. We compare the addresses and key personnel of each of these ambiguous venture organizations with the information reported in the prospectus. If we are not virtually certain that the venture organizations in the prospectus and the database are the same, we do not code it as a match. For each investor, we code the venture organization, the particular venture fund investing in the firm, and the size of the stake before and after the offering. This process leads to the identification of 885 IPOs in which a venture capitalist served as a director or a venture capital fund was a blockholder.

In each year, we calculate the market value of the equity stakes in firms going public held by each venture capital organization. This value is the number of shares held by the venture organization multiplied by the IPO offering price. We then sum the market values for each IPO in a given year to obtain an annual performance number for each venture capital organization. We then sum across all venture organizations in a given year to get a measure of venture industry performance.

In Figure 2, we graph the time series of venture capital commitments and the market value of all firms brought public by venture capitalists in each year from 1969 through 1994. We see that from 1969 through 1979, commitments to venture capital and venture-backed IPOs were quite low. Starting in 1980, both commitments to the venture capital industry and the value of firms brought public by venture capitalist rise. The rise of both reversed in 1983. After 1983, it appears that the shift in venture-backed

[57]In many cases, individual investors (often called "angels") will describe themselves as venture capitalists. Groups of individual investors often make their investments through partnerships, which frequently are given a name not unlike those of venture capital organizations.

IPO market leads to changes in commitments to new venture funds. For example, increases in the market value of venture-backed IPOs in both 1986 and 1991-1992 preceded resurgences in the venture capital market.

The relation between capital gains taxes and venture capital commitments is documented in Figure 3. The relation is clearly negative. In the 1970s, high capital gains tax rates were associated with low levels of venture capital fundraising. Increases in the capital gains tax rates in 1988 were followed by reductions in venture capital commitments, while the reduction of capital gains for long-held investments in 1993 was followed by a rise in venture fundraising. This negative relation between venture capital funding levels and capital gains tax rates is clearly only suggestive, because the influence of multiple factors needs to be examined.

Detailed information on the nature of commitments is shown in Table 1. Several patterns are prominent. First, the volatility of commitments is readily apparent. The level of fundraising (expressed in 1994 dollars) can vary dramatically from one year to the next. The volatility in venture fundraising is mirrored by a similar volatility in the IPO market, both for venture-backed companies and for the entire IPO market. We see the dramatic shift from individuals to pension funds over the past fifteen years as the primary capital source for new venture funds.[58]

In order to assess the impact of each of these variables controlling for the others, we present multivariate regressions in Table 2. Our approach here and in the individual firm regressions is to estimate reduced-form specifications and identify which factors potentially work through demand shifts and which factors work through supply shifts. The time series of data runs from 1972 through 1994. The dependent variable is the natural logarithm of real commitments to the venture capital industry (in millions of 1994 dollars). We present regressions for commitments to the entire venture capital industry, as well as four subgroups: taxable investors, tax-exempt investors, individuals, and pension funds. The independent variables include the natural logarithm of the market value of firms brought public by venture organizations in the previous year (in millions of 1994 dollars), the real return on Treasury bills in the previous year, the real CRSP value-weighted stock market return in the prior year, the previous year's real GDP growth, a dummy variable that equals one for years after 1978 when ERISA's prudent man rule was clarified, and the top marginal capital gains tax rate.

Changes in ERISA's prudent man rule are associated with greater commitments to the venture capital industry, but the effect is not significant for commitments by taxable investors and individuals. As expected, the strongest effect of ERISA's clarification is on contributions by pension funds. An F-test of the null hypothesis that the coefficient for pension funds is significantly different from the coefficient for individuals and taxable investors shows that ERISA's effect on contributions by pension funds is different at the five percent level. This is consistent with a supply side effect: the easing of pension fund restrictions increased the number of investors wishing to invest in venture capital funds.

Increases in capital gains tax rates have a consistently negative effect on contributions to the venture industry, although the effect is only significant for contributions to the entire industry and contributions by pension funds.[59] While we do find an effect of capital gains taxes on venture capital commitments, it does not appear to be working through the supply side. If changes in the capital gains tax rates had a first-order effect on investors' willingness to invest in venture capital, then the effect would be strongest for

[58]The measures of the sources of funds are taken from various issues of Venture Economics' *Venture Capital Journal.*

[59]The coefficients on capital gains tax rates are not significantly different from one another across different investor classes. The purpose of the comparison is simply to show whether capital gains tax rates affect taxable investors only (as the supply effect would predict) or whether they affect all investors equally (as the demand effect would predict).

individuals and taxable parties. The opposite is true. As Poterba (1989) suggests, the effect of changes in the capital gains tax rate is likely to come through changes in the demand for venture capital. More and better quality managers are incented to become entrepreneurs when the capital gains tax rate declines and thus the demand for venture capital increases. This increase in demand leads to a greater quantity of venture capital being supplied in equilibrium.

Once other factors are included, the value of firms taken public by venture organizations in the previous year does not appear to have a dramatic effect on contributions. While we cannot rule out a role for IPOs creating liquidity in the venture sector and potentially affecting contributions, we cannot find an effect in the multivariate regressions. This finding is contrary to the arguments of Black and Gilson (1998), who emphasize the importance of a vibrant public market in the development of a venture capital industry. It is consistent, however, with the experience of Israel and Singapore, whose venture industries have experienced dramatic growth without having strong domestic public equity markets.

Of the macroeconomic variables, only real GDP growth is important. Increases in the real rate of growth lead to greater commitments to venture funds. Once again, this suggests that increasing demand for venture capital is an important determinant of the quantity. Robust economic growth creates new opportunities for entrepreneurs and increases demand for such capital.

One concern may be that because we are using time series observations on venture fundraising and the independent variables, the results may be affected by serial correlation in the error terms. The Durbin-Watson statistics for each of the regressions were between 1.88 and 2.00, indicating that such serial correlation does not affect the results. As a diagnostic, we also ran Cochrane-Orcutt regressions using a lag term which did not materially change the results.

4.2. State-level venture activity

One difficulty with the analysis in the previous section was the relatively small number of observations. In order to gain additional power for our tests of market-wide venture activity, we examine venture capital activity in each of the fifty states and the District of Columbia from 1976 through 1994. We can then examine how state level demand and supply factors affect venture investing in those states.

We employ a slightly different approach here than in Sections 4.1 and 5: rather than examining the formation of venture funds in each state, we measure the actual venture capital investments. This reflects the difficulty of assigning venture organizations to particular states. Many venture organizations have multiple offices, which may account for differing shares of the investments. Venture organizations' headquarters may reflect the need to be proximate to their sources of capital and not their portfolio firms. For instance, many venture organizations are based in New York City, even though this has historically been the site of few start-up firms. This pattern is particularly true for groups specializing in the later-stage investments, which typically occur after other groups (who may be geographically more proximate to the portfolio firm) have already joined the board [Lerner (1995)].

We once again use the data of Venture Economics to determine venture capital activity by state. In this case, we undertake a special tabulation of the number of companies financed and dollar volume of financing in each state and year between 1976 and 1994. We include all investments by private equity groups into young entrepreneurial firms, but exclude investments into leveraged buyouts and restructurings by groups that primarily make venture capital investments.

We also collect a variety of additional data on a state by state basis. Gross state product has been compiled on an annual basis by the Department of Commerce's Bureau of Economic Analysis (1997) [also used was Friedenberg and Beemiller, (1997)]. For each state, we compiled the total amount of research performed in industry and in academia, regardless of funding source. The state industrial R&D data was compiled by the National Science Foundation (NSF) as part of the "Survey of Research and

Development in Industry" (1980, 1998b). The data posed two problems. First, since 1978 this information has only been collected on a biannual basis. Thus, it was necessary to impute the missing years. Second, certain states are persistently missing. In these instances, the unassigned R&D in each region is assigned to each suppressed state on the basis of its Gross State Product.[60] The allocation of academic R&D expenditures by state is determined the NSF's annual "Survey of Research and Development Expenditures at Universities and Colleges" (1998a). We obtain the marginal state tax rate on capital gains through the use of the TAXSIM tax simulation program. We compute the impact of $1000 of capital gains on a wealthy individual in each state and year, controlling for the possible deductibility of state taxes in Federal taxes. [The program is described in Feenberg and Coutts (1993); the simulation and the resulting data are reproduced at <http://www.nber.org/~taxsim/state-rates>.]

Table 3 looks at venture capital activity in each state by tabulating the total number of companies that received venture capital and the total amount of venture capital invested from 1976 through 1994. The tremendous concentration of investment in four states is clearly evident. California has by far the most venture investing activity with nearly $20 billion invested (in 1994 dollars). Massachusetts, New York, and Texas are the next most active states and account for the bulk of the remaining capital. It is also clear that many states have almost no venture capital activity. We seek to explore these patterns in a regression framework.

In Table 4 we present state fixed-effects regressions for the level of venture capital investment per capita (in millions of 1994 dollars) and the number of companies receiving venture capital per capita. We employ an observation for each year in each state, *i.e.*, a balanced panel. Independent variables include market-wide measures used in the regressions in Table 2 (logarithm of IPO activity, the previous year's real T-bill return, and the previous year's equity market return). In addition, we include several variables that might proxy for state-level demand conditions. These include the previous year's growth in state Gross State Product (GSP) per capita as well as measures of last year's academic and industrial expenditure on R&D (in millions of 1994 dollars) per capita. The R&D expenditure potentially captures demand effects of high-technology firms. If R&D is higher in a state, it may mean that the number of potential entrepreneurs with promising ideas may be greater.

In addition, we include a dummy variable that is equal to one after 1978 to capture the effect of changes in ERISA's prudent man rule. Finally, we include several measures of the capital gains tax rate burden. We first control for state and Federal capital gains taxes separately by including the maximum marginal state and Federal capital gains tax rate separately. We then add the Federal and state rates to create a variable which captures the total capital gains tax burden in that state.[61]

Table 4 shows that both industrial and academic R&D spending are significantly related to state-level venture capital activity. Increases in state R&D levels increase both the amount of venture capital invested as well as the number of firms receiving venture capital. This result suggests that both academic and industrial R&D spending are potentially important for the creation of entrepreneurial firms that demand venture capital.

Similarly, growth in GSP per capita is positively related to venture capital activity. This result, consistent with the aggregate results, may indicate the importance of the demand effects, *i.e.*, it is important to have a strong growing economy to create new firms that need venture capital financing.

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[60]For instance, in 1977, as in earlier and later years, data for New Hampshire and Vermont are suppressed. Of the $2.4 billion of R&D spending in New England in that year, $2.3 billion is accounted for by Connecticut, Maine, Massachusetts, and Rhode Island. We divide the remaining amount 65%-35% between New Hampshire and Vermont, proportional to their Gross State Products in that year.

[61]The state tax measure only includes the marginal impact: *i.e.*, any savings in Federal taxes due to the deductibility of state taxes are factored in. All regressions include state fixed-effects.

The dummy variable measuring the shift in ERISA policy continues to have a positive effect in the state-level regressions. After the clarification of ERISA, the amount of venture capital invested per capita as well as the number of firms receiving venture capital per capita increases. Finally, capital gains tax rates continue to matter. In the regressions including both state and Federal rates, it is only the Federal rate that is significantly related to venture capital activity. The state capital gains tax rate is, however, always negatively related to venture capital activity and is of the same order of magnitude as the effect of Federal rates. The combined Federal and state capital gains rate is also significantly related to venture capital activity. The result confirms the earlier results. Capital gains tax rates do appear to be negatively related to venture capital activity.

5. Individual venture organization results

5.1. Summary statistics

In this section, we examine fundraising patterns by individual venture organizations. We perform three levels of analysis. First, we present summary statistics for the database, both in its entirety and segmented by year. We then analyze factors affecting the fundraising ability of individual venture organizations. Finally, we examine the decision of venture organizations to raise funds with a focus on early- and seed-stage firms. The importance of early- and seed-stage funds in creating new firms is widely recognized. Many of the efforts to stimulate venture activity focus on stimulating seed capital funds. Understanding the unique factors affecting the decision to target these firms is important for potential policy decisions. We examine fund information collected by Venture Economics from 1961 through 1992.

Table 5 presents information on the completeness of the venture fundraising database. In all, we have information on 1294 venture capital funds. Of those, we have information on the fund size and closing date for 846 (20 of these are missing month of closing). The average venture organization in the sample raised 2.23 funds while the median raised only 1. The maximum number of venture funds raised by an organization is 25. The average venture organization raised $126 million in 1994 dollars while the largest organization had raised over $2 billion.

The time series distribution of our sample is presented in Table 6. We see growth in both the number of funds raised and dollar volume of commitments in the early- and mid-1980s. The sample also appears to exhibit a slight growth in the size of funds raised (in constant 1994 dollars). If we look at the sum of all the funds in our sample, we have data on $45.0 billion in venture funding which represents nearly all the capital raised by organized venture capital partnerships during the sample period.[62] The lack of size data for 448 of the funds does not impart bias to our results. Our data cover almost all the capital raised over the sample period and, hence, the results are clearly applicable to the most important firms.

5.2. Fundraising regression results

We analyze firm level fundraising by using one yearly observation for each venture organization starting with the year that they raise their first venture capital fund. The dependent variable is either a dummy variable indicating whether the venture organization raised a fund or the amount of money (in millions of 1994 dollars) raised in that year. Independent variables include the age of the venture organization, the amount of money it raised during the previous ten years[63] (in millions of 1994 dollars), the value of equity

[62]The Federal government does not collect numbers on venture capital inflows. The Venture Economics database, however, corresponds closely to those of another consulting firm, Asset Alternatives, as well as estimates by practitioners.

[63]We look at money raised over the previous ten years because that is the specified life-span of a typical venture capital limited partnership agreement. The ten-year sum provides the best available estimate of capital under management.

held by this venture organization in firms brought public in that year and the previous year, the value of all venture-backed firms brought public in the previous year, real GDP growth in the previous year, the previous year's Treasury bill return, the previous year's stock market return as measured by the annual return on the CRSP value weighted market index, a dummy variable that equals one after 1978 (indicating years after the clarification of the ERISA prudent man rule), and the top marginal capital gains tax rate on individuals.

We estimate a Heckman two-stage model. The Heckman model estimates two equations. The first is the probability that a fund was raised in a given year. The second equation then estimates the amount raised given that a fund was raised in a particular year. This two-stage model is appropriate if the correct decision is that venture capitalists first decide whether to raise a new fund or not. Once they decide to raise a new fund, the venture capitalists then decide the size of fund they wish to raise. The two equations give us insights about factors that affect the probability of raising a new fund and ones that primarily affect the optimal fund size.

Table 7 gives the results from the Heckman models. The first regression in each model gives the probability of raising a new fund, while the second regression gives the size of a fund conditional on it being raised. We find that neither the capital gains tax rate nor ERISA's clarification have a significant effect on the probability of a venture organization raising a new fund. The ERISA dummy has no effect on the size of the fund either. The capital gains tax rate does, however, have a significant effect on the size of the fund raised. Lower capital gains tax rates are associated with larger funds. This would be expected if venture organizations raised new funds on a normal cycle that was typically unaffected by external factors. Changes in the capital gains tax rate may affect the quantity of good start-ups to finance as managers are induced to start firms. The greater quantity of good projects would lead venture capitalists to raise larger funds.

We also find that firm performance has a dramatic effect on fundraising. Both the value of equity held in firms taken public by the venture capital firm in the current year and in the previous year have a positive effect on the probability of raising a new fund and the size of the fund. The effect of the previous year's IPO volume is nearly four times as large as the current year's. This might be due to the long process of raising a new fund (which may take many months). Venture organizations go on "road shows" and gauge investor interest, sign up prospective investors, and generate the necessary documents prior to closing. The more relevant performance is probably the previous year's returns, which are foremost in investors' minds during fundraising.

Reputation also appears to have a positive effect on the size of the fund raised. Older and larger venture organizations have higher probabilities of raising funds and raise larger funds. The reputation variable potentially captures beliefs about future returns not captured in recent performance variables. The effect of venture organization size is particularly strong on the size of the fund raised. This could indicate that venture organization size is a good proxy for reputation. Venture organization size might also measure the need to raise larger funds. Large venture organizations may have more employees and general partners. In order to keep all of them working at capacity, the minimum fund size needed is substantially higher.

We find that the Treasury bill return in the previous year is positively related to the probability of raising a new fund. This effect may stem from the rapid increase in funds being raised in the early 1980s at a time when real interest rates were high. Both the probability of raising a fund and the size of a new fund raised first decline and then increase with time from the previous fund.[64]

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[64]The regression results are robust to various segmentations of the data, e.g., examining firms located on the West Coast and East Coast.

We present the fixed-effects regression models in Table 8. The fixed-effects models include dummy variables for each venture organization that are intended to pick up unmeasured firm-specific factors. If we find a result even after controlling for firm fixed effects, we can be confident that the effects are robust. We could not estimate the fixed-effects Heckman model. Therefore, we run two separate regressions. The first is a fixed-effects logit which estimates the probability of raising a fund in a given year. The second regression is a fixed-effects least squares regression that estimates the size of funds raised conditional on a fund being raised. The approximation to the two-stage maximum likelihood Heckman model is consistent in the estimations without the fixed effects, so we are confident that the results in Table 8 are reasonable [Maddala (1987)].

In both specifications, the capital gains tax rate continues to be a significant factor in venture fundraising. A decrease in the capital gains tax rate increases the size of funds raised in all the specifications. In the first model, the ERISA dummy variable has an important impact. Controlling for firm factors, the ERISA clarification leads to a greater probability of raising a new fund.

Venture organization performance (as measured by the value of equity stakes in initial public offerings) continues to have a positive effect on fundraising. In the two-stage model with firm fixed effects, the probability of raising a fund increases with greater performance, but the size of the fund does not appear to be affected. We find, however, that the reputation variables have mixed signs in the fixed-effects regression, which are different from the regressions without the firm fixed effects. In the two-stage model, the probability of raising a fund is lower for older and larger organizations, but the fund size is larger. As a firm ages, the probability of raising a new fund declines, although the size of funds being raised increases. This lower probability of raising a fund may reflect the retirement of partners within older venture organizations. Unconditionally, older firms are more likely to raise a fund because of their better track record. Controlling for firm effects, however, as a firm ages, it becomes less likely to raise a fund.

5.3. Stage focus results

We also undertake an analysis of the ability of venture capital organizations to raise a fund that focuses on early-stage investments. The early-stage venture market is often seen as being critical to the success of later-stage investments. Early-stage funds provide new firms with critical financing in their infancy [see for instance OECD (1996)]. Many of the policy initiatives undertaken across the country and around the world are aimed at increasing the availability of early-stage capital. Similarly, firms in their very early stages are the most prone to capital rationing and liquidity constraints because the uncertainty and asymmetric information are the greatest. If we can understand the incentives to raise a focused fund, we might be able to understand industry dynamics better and may make better recommendations about promoting new entrepreneurial firms.

We divide firms into two categories in this analysis. We indicate whether the funds analyzed above have a stated investment focus on early-stage firms only. (Venture Economics characterizes each fund's focus in their database.) Table 9 presents summary statistics for venture funds that have a stated early-stage focus and those that do not. We find that funds focusing on early-stage investments are significantly smaller, with a mean [median] size of $42 [$25] million, than are funds that do not focus on early-stage investments (mean of $57 [$36] million). This makes sense because early-stage investments are typically smaller than later-stage investments. Gompers (1995) finds that the average early-stage investment is only half as large as the mean later-stage investment. Because the amount of time spent during the investment and monitoring process (e.g., due diligence, negotiations, etc.) and the need for oversight after the investment is similar, early-stage funds are usually smaller.

We also find that early-stage funds tend to be raised by venture organizations that are slightly older and larger. One possibility is that older, more experienced venture organizations have the necessary

knowledge to raise a focused fund. The early-stage funds are, on average, more recent and are more likely to be raised on the West Coast. Clearly, the mix of investments on the West Coast, primarily California, is heavily concentrated on early-stage, technology-based companies. East Coast firms are more balanced and tend to invest in greater fractions of later-stage companies.

In Table 10 we present multivariate regressions analyzing the determinants of fund focus. We use each new venture capital fund as an observation and examine whether it had an early-stage focus. As the summary statistics hinted, smaller funds are more likely to have an early-stage focus. Similarly, we find that firms on the West Coast are more likely to raise an early-stage fund. Finally, we find that a venture organization is more likely to raise a fund with an early-stage focus after the Department of Labor's clarification of ERISA's prudent man rule. This greater probability following ERISA change is potentially due to the clarification stating that investments would be judged prudent not by their individual risk, but by their contribution to portfolio risk. Prior to this amendment, early-stage funds may have been viewed as too speculative and may have had a more difficult time raising money than a later-stage or general purpose venture capital fund. After the amendment, venture organizations could raise focused funds without worrying that pension funds would avoid it out of concern over its perceived riskiness.

5.4. Alternative Explanations

Several alternative explanations may account for the findings in Sections 4 and 5. First, the supply and demand for venture capital may be affected by the supply of substitute financing. We have attempted to control for the cost of credit by including the real interest rate. In periods of high real interest rates, venture capital may be more attractive from the entrepreneur's perspective. Similarly, if the availability of bank financing were a major factor in the determination of venture capital commitments, then we should have seen an increase in venture capital commitments in the late 1980s and early 1990s, when bank credit to young, small firms substantially declined. Instead, we see a decline in venture capital commitments over this time period, indicating that bank credit and venture fundraising moved together.

A second alternative explanation for our results on capital gains taxes and venture commitments may be the inability to accurately measure expected GDP growth. If expected GDP growth is somehow correlated with capital gains tax rates, then we might be incorrectly interpreting the significance to capital gains tax rates. In unreported regressions, we modeled expected GDP growth using the previous four years of real GDP growth. Instead of lagged GDP growth, we reestimated the regressions using the expected GDP growth rate. Results were qualitatively the same as in Sections 4 and 5. This is not surprising since the expected GDP growth rate is primarily affected by last year's growth.

Finally, the growth in venture capital commitments may have less to do with policy changes and more to do with changes in the amount of technological opportunities. In fact, the state level R&D expenditures indicate that this may be the case. If changes in technological opportunity were causing increases in venture capital investments, we would expect several measures of technological innovation to lead increases in venture fundraising. In particular, Kortum and Lerner (1998) show that a surge of patents occurred in the late 1980s and 1990s. This suggests that some of the recent growth in venture capital fundraising in the mid-1990s may be due to increases in technological opportunities. The increase in venture fundraising in the late 1970s and 1980s (the period of our sample), however, does not seem to be caused by similar technology shifts. Similarly, the state level analysis shows that even controlling for R&D spending, regulatory policies still have an effect.

5. Conclusion

In this paper, we examine the determinants of fundraising for the venture industry and individual venture organizations. We examine supply and demand effects as well as the importance of individual firm performance and reputation.

We find that demand for venture capital appears to play a critical role. Higher GDP growth and increases in R&D spending lead to greater venture capital activity. We also find that capital gains tax rates matter, with lower rates leading to a greater quantity of venture capital raised. The effect, however, appears to stem from a greater demand for venture capital: commitments by tax-exempt pension funds are the most affected by changes in the capital gains tax rate. We find evidence that ERISA clarification in rules governing pension fund investment have generally increased commitments to the industry.

Fund performance is an important determinant of the ability of venture organizations to raise new capital. Firms that hold larger equity stakes in firms that have recently gone public raise funds with greater probability and raise larger funds. Reputation, in the form of firm age and size, also positively impacts the ability to raise new capital.

We also provide evidence that the decision to raise an early-stage venture fund has been affected by pension regulations. The probability of raising a focused fund increased after ERISA's clarification. We also find greater early-stage activity in smaller funds and venture organizations on the West Coast where technology-based startups are more prevalent.

Our research has a variety of implications for policy makers who wish to stimulate venture capital activity. The fundraising results indicate that regulatory reform and policy decisions may have an effect on commitments to the venture industry. While the capital gains tax rate is an important driver of venture capital fundraising, blanket reduction in capital gains tax rates may be a blunt instrument for promoting venture capital. Our analysis suggests that an important factor for the increase in venture capital is probably increases in the number of high quality startups. The greater number of good firms leads to more demand for venture capital. Policies that increase the relative attractiveness of becoming an entrepreneur and promote technology innovation probably would have more of an effect on venture capital investments than an across the board cut in the capital gains tax rate. Furthermore, the results highlight the highly localized nature of venture capital activity. Countries that wish to promote venture capital activity may consider concentrating efforts rather than spreading resources uniformly around the country. This is in contrast to many of the efforts that various countries have instituted.

The results also raise a series of questions for further research. In general, the role of reputation and performance as determinants of fundraising is consistent with earlier literature for other types of money managers. The decision to invest is clearly predicated on the expectation of future returns, and both past performance and reputation are components of the expected future returns. But in recent years, many of the most established venture organizations in the U.S. have experienced internal corporate governance problems and have been disbanded. The issue of who carries the reputation with them is important. Does reputation follow general partners who start their own fund or must they establish new reputations? In markets without experienced venture capitalists, how can the lack of reputation be overcome? Clearly, more work is necessary.

Another set of unanswered questions relates to the effectiveness of public efforts to transfer the venture capital model to other regions. Even if venture capital organizations spur technological innovation in the United States, it is not evident that the model can be seamlessly transferred abroad. Different employment practices, regulatory policies, or public market avenues might limit the formation these funds [see Black and Gilson (1998) for a discussion]. Even if it were feasible to transfer such efforts, public economic development programs can be subject to political manipulation: e.g., pressures to award funds to politically connected businesses.

On the other hand, overseas venture initiatives may be able to benefit from the experience of venture organizations in the United States. In particular, the Israeli Yozma program seems to have successfully captured "spillovers" of knowledge from U.S. and British venture organizations. In contrast to many forms of government intervention to boost economic growth, the implementation of these programs has

received little scrutiny by economists. [Two recent exceptions are Irwin and Klenow (1996) and Lerner (1996).] This is a ripe area for further exploration.

Venture capital is increasingly regarded as an important component of the U.S. economic landscape. While policy makers have often tried to affect the flow of funds into the sector, little has been known about the real impact of such policy measures. Our paper begins to answer those questions and points towards areas for future research.

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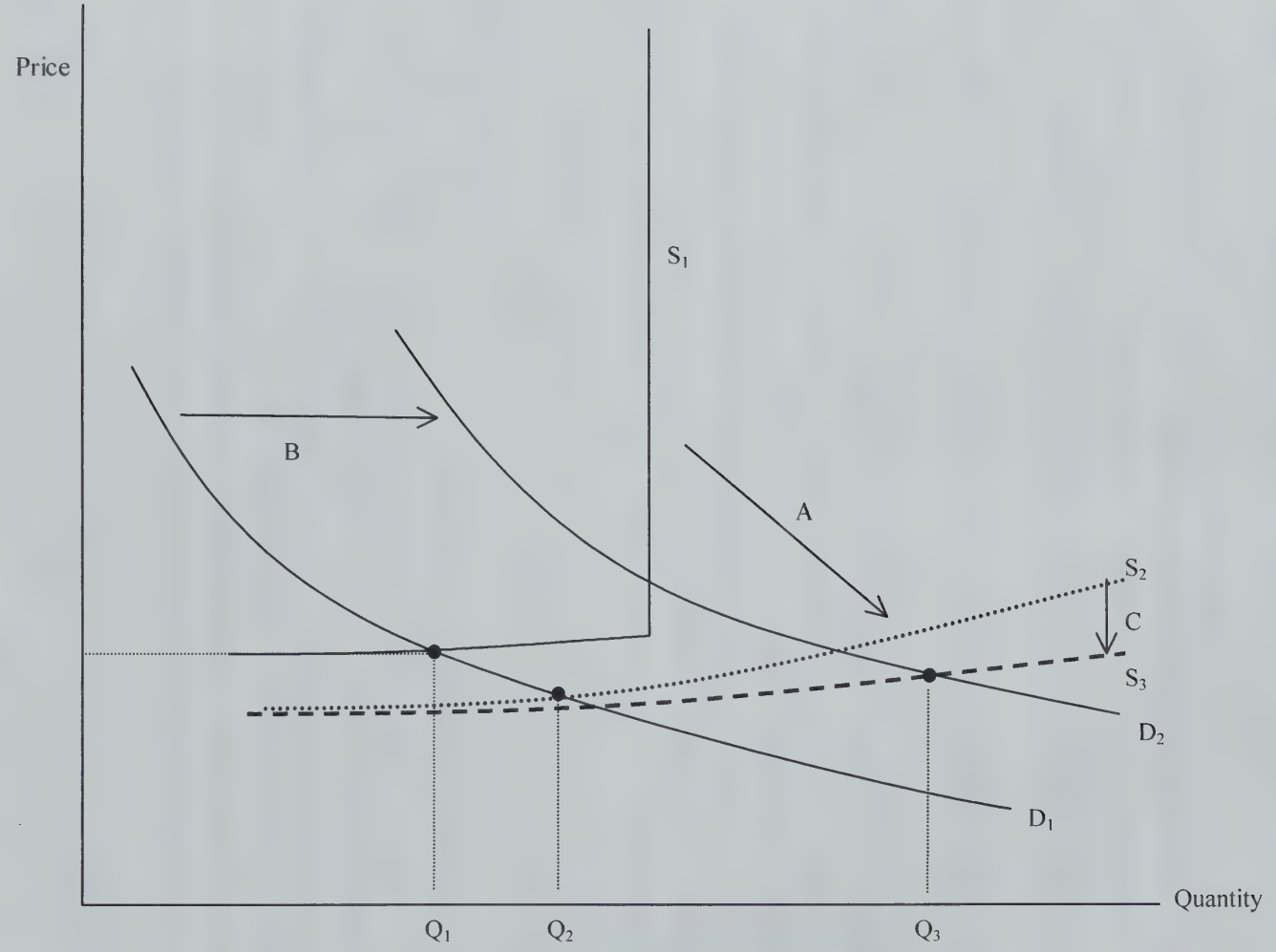

Figure 1. Supply and demand in venture capital. This figure gives a graphical illustration for the changes in supply and demand in the venture capital market. Equilibrium prior to the clarification of ERISA is represented by Q_1. After ERISA, the supply curve shifts down to S_2 (A) and the new equilibrium quantity of venture capital is Q_2. Capital gains tax reductions move both demand to D_2 (B) and supply to S_3 (C) and the equilibrium quantity of venture capital moves to Q_3.

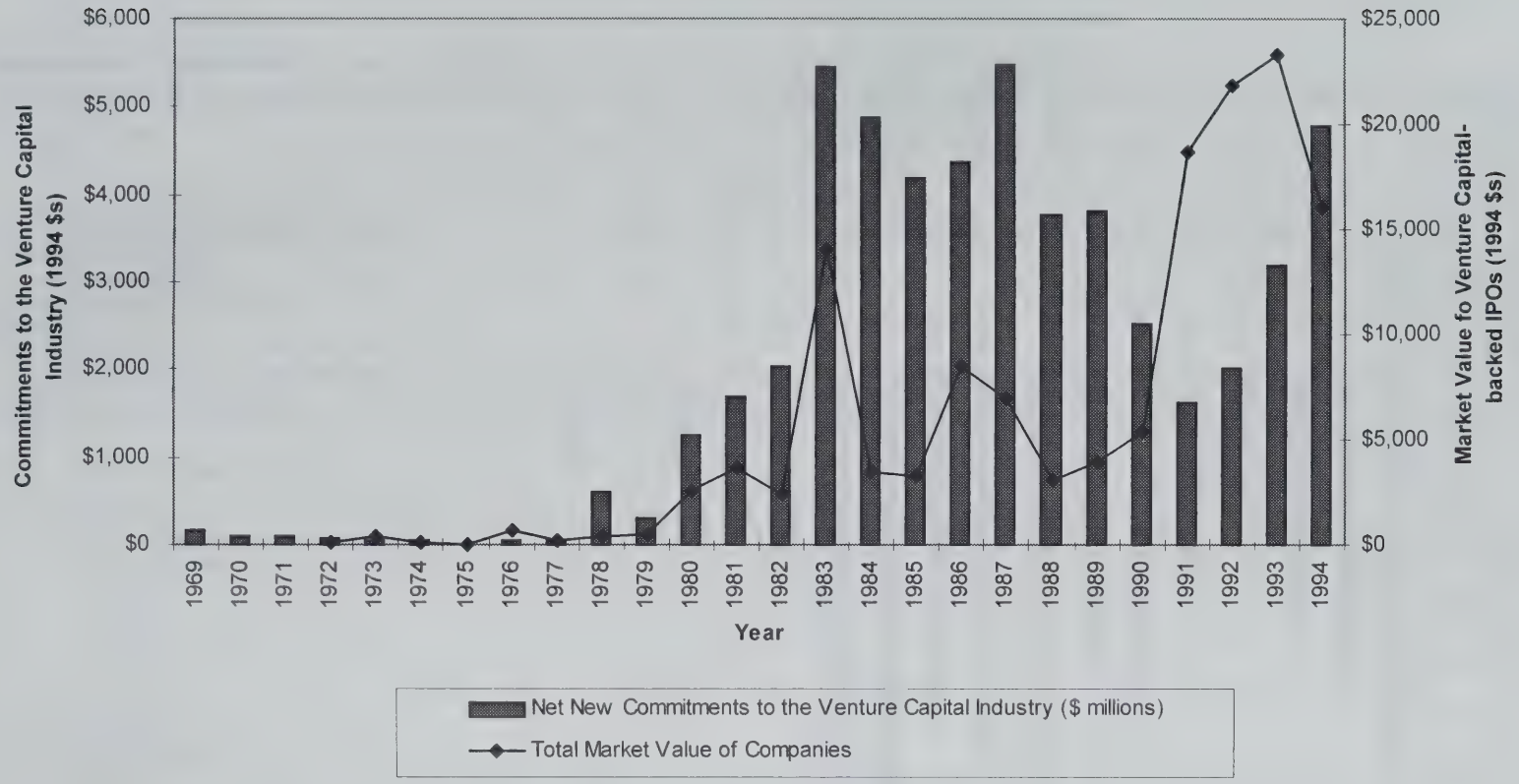

Figure 2 Venture fundraising and IPO activity. The bar graph shows annual commitments to the venture capital industry in millions of constant 1994 dollars. The line graph shows the annual market value of all venture capital-backed firms issuing equity in an initial public offering.

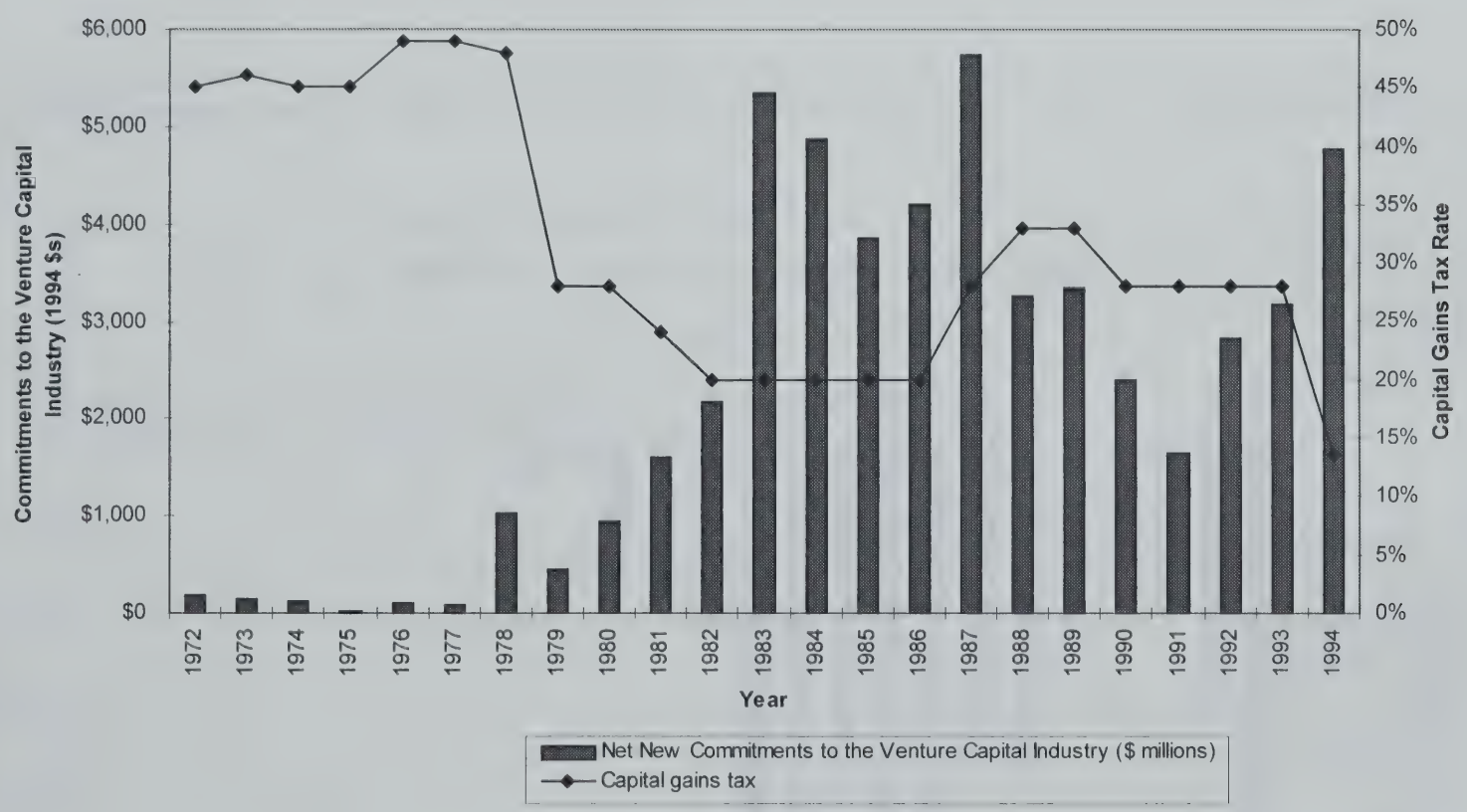

Figure 3 Venture fundraising and capital gains tax rate. The bar graph shows annual commitments to the venture capital industry in millions of constant 1994 dollars. The line graph shows the highest marginal capital gains tax rate effective in that year.

Table 1. Venture capital industry summary statistics. All figures in millions of 1994 dollars.

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Net New Commitments to Independent Venture Capital Partnerships (1994 $ millions)	$427	$483	$1,245	$1,712	$2,089	$5,453	$4,839	$4,191	$4,427	$5,378	$3,718	$3,458	$2,507	$1,529	$2,011	$2,545	$4,766
Source of Venture Contributions																	
Corporations	10%	17%	19%	17%	12%	12%	14%	12%	11%	10%	12%	20%	7%	5%	3%	8%	9%
Individuals	32%	23%	16%	23%	21%	21%	15%	13%	12%	12%	8%	6%	11%	12%	11%	7%	12%
Pensions Funds	15%	31%	30%	23%	33%	31%	34%	33%	50%	39%	47%	36%	53%	42%	42%	59%	47%
Foreign	18%	15%	8%	10%	13%	16%	18%	23%	11%	14%	13%	13%	7%	12%	11%	4%	2%
Endowments	9%	10%	14%	12%	7%	8%	6%	8%	6%	10%	11%	12%	13%	24%	18%	11%	21%
Insurance Companies	16%	4%	13%	15%	14%	12%	13%	11%	10%	15%	9%	13%	9%	5%	15%	11%	9%
Venture Capital-Backed Initial Public Offerings																	
Number of Companies	6	4	27	68	27	121	53	46	97	81	35	39	42.00	122	157	165	136
Total Amount Raised	$231	$95	$563	$946	$661	$3,605	$863	$979	$2,546	$2,156	$851	$1,068	$1,158	$4,031	$4,702	$4,923	$3,351
Total Market Value of Companies	$501	$335	$3,519	$4,436	$2,860	$16,694	$4,059	$3,805	$10,136	$8,078	$3,516	$4,183	$5,536	$19,269	$22,476	$23,531	$16,018
All IPOs																	
Number of Companies	42	103	95	227	100	504	213	195	417	259	96	254	213	403	605	819	646
Total Amount Raised	$835	$1,189	$1,460	$3,346	$1,461	$11,395	$2,956	$3,698	$10,204	$6,118	$2,694	$14,699	$10,481	$26,001	$41,057	$58,248	$33,841
Total Market Value of Companies	$2,320	$4,334	$7,662	$13,423	$6,585	$48,140	$12,534	$13,570	$37,998	$27,908	$13,242	$46,445	$28,841	$72,668	$104,775	NA	NA

Source: Authors' analysis of Venture Economics' database, Brav and Gompers [1997], and various issues of the *Venture Capital Journal.*

Table 2. Regressions for industry-wide fundraising. The dependent variable is the natural logarithm of the amount of venture capital commitments (in millions of 1994 dollars) for either all independent private venture capital funds or only those commitments by various groups of investors from 1972 through 1994. Taxable commitments are defined as all commitments from individuals, corporations, or insurance companies. Nontaxable contributions are defined as those from pension funds and endowments. Independent variables include the natural logarithm of the market value of all venture capital-backed firms issuing equity in the previous year (in millions of 1994 dollars), the previous year's real growth in gross domestic product (GDP), the return on t-bills in the previous year, the previous year's CRSP value weighted stock market return, a dummy variable that equals one if the Department of Labor clarified the prudent man rule and allowed pension investment in venture capital (equals one for all years after 1978), and the highest marginal capital gains tax rate effective in that year. All regressions are ordinary least squares estimates. [t-statistics are in brackets.]

	Dependent Variable Natural logarithm of commitments to the venture capital industry (millions of 1994 $):				
Independent Variable	Total	Taxable	Tax-exempt	Individuals	Pensions
Natural logarithm of value of all venture capital-backed IPOs in previous year (millions of 1994 $)	-0.0124 [-0.06]	-0.0300 [-0.11]	-0.2453 [-1.71]	0.0046 [0.17]	-0.3037 [-1.92]
Previous year's real GDP growth	13.28 [2.01]	16.08 [2.34]	14.48 [3.92]	14.92 [2.10]	12.38 [3.05]
Previous year's t-bill return	0.0022 [0.04]	0.0436 [0.64]	-0.1212 [-3.28]	0.0417 [0.59]	-0.1556 [-3.83]
Previous year's equity market return	0.3836 [0.48]	-0.2240 [-0.22]	0.1648 [0.30]	-0.3920 [-0.36]	-0.1092 [-0.18]
Was ERISA's prudent man rule clarified?	2.172 [3.05]	0.8598 [1.25]	2.183 [5.92]	0.6299 [0.89]	2.454 [6.05]
Capital gains tax rate	-3.835 [-1.66]	-2.068 [-0.96]	-1.803 [-1.65]	-2.498 [-1.52]	-2.726 [-2.14]
Constant	6.551 [3.01]	5.3195 [1.95]	8.579 [5.85]	5.307 [1.88]	8.918 [5.53]
Adjusted R^2	0.824	0.303	0.874	0.250	0.884
p-value of F-statistic	0.000	0.000	0.000	0.000	0.000
Number of observations	22	17	17	17	17

Table 3. Summaries of venture capital activity by state. The sample is all venture capital investments by independent venture organizations by state from 1976 through 1994. The table indicates the number of companies receiving venture capital and total amount of venture capital invested in each state during this time period. For those with size data, the distribution of total funds committed in each state is also tabulated with size denoted in millions of 1994 dollars.

State	Companies Financed	Total Venture Capital Invested	State	Companies Financed	Total Venture Capital Invested
Alaska	3	$52.11	Montana	17	$49.19
Alabama	75	199.12	Nebraska	15	8.05
Arizona	189	693.91	Nevada	22	25.77
Arkansas	12	14.69	New Hampshire	136	344.32
California	6,154	19,967.67	New Jersey	643	2,019.21
Colorado	609	1,557.01	New Mexico	38	56.47
Connecticut	486	2,094.18	New York	811	2,369.43
Washington, DC	70	210.95	North Carolina	239	612.23
Delaware	26	42.62	North Dakota	4	28.23
Florida	338	779.66	Ohio	342	1,351.21
Georgia	395	872.04	Oklahoma	60	134.78
Hawaii	4	1.23	Oregon	297	789.34
Idaho	12	58.46	Pennsylvania	575	2,292.38
Illinois	514	1,879.06	Rhode Island	85	226.61
Indiana	137	260.33	South Carolina	37	165.86
Iowa	60	143.39	South Dakota	15	7.57
Kansas	46	90.33	Tennessee	235	844.14
Kentucky	59	173.54	Texas	1,254	3,861.13
Louisiana	45	137.59	Utah	117	246.69
Maine	50	126.77	Vermont	313	969.05
Maryland	321	989.15	Virginia	17	61.55
Massachusetts	2,276	5,886.44	Washington	327	835.79
Michigan	267	808.56	West Virginia	16	33.68
Minnesota	483	837.11	Wisconsin	144	269.40
Mississippi	26	32.01	Wyoming	5	4.22
Missouri	107	611.60			

Table 4. Regressions for state level venture capital activity. The dependent variable is the venture capital activity at the state level (either amount invested in millions of 1994 dollars per million residents or the number of companies receiving financing per 1,000 residents) for each year from 1976 through 1994. Independent variables include the natural logarithm of the market value of all venture capital-backed firms issuing equity in the previous year (in millions of 1994 dollars), the previous year's real growth in gross state product (GSP) for that state per capita, the natural logarithm of the previous year's expenditure on academic and industrial R&D per capita in the state (in 1994 dollars), the return on t-bills in the previous year, the previous year's CRSP value weighted stock market return, a dummy variable that equals one if the Department of Labor clarified the prudent man rule and allowed pension investment in venture capital (equals one for all years after 1978), and the highest marginal capital gains tax rate effective in that year at the state and national level. All regressions include state fixed effects (not reported). [t-statistics are in brackets.]

	Dependent Variable			
	Logarithm of real venture capital investment in the state per million residents		Number of companies receiving venture financing in state per 1,000 residents	
Independent Variable				
Logarithm of value of all venture capital-backed IPOs in previous year (millions of 1994 $s)	-0.2008 [-3.35]	-0.1973 [-3.37]	-0.2414 [-1.46]	-0.2372 [1.46]
Logarithm of previous year's real GSP per capita	0.5343 [1.73]	0.5438 [1.77]	4.5621 [4.59]	4.5854 [4.68]
Previous year's real GSP growth in the state	0.0480 [3.11]	0.0478 [3.11]	0.1609 [3.45]	0.1605 [3.45]
Logarithm of previous year's real expenditure on academic R&D per capita in the state	0.7939 [4.88]	0.8032 [5.15]	0.1898 [0.36]	0.2044 [0.39]
Logarithm of previous year's real expenditure on industrial R&D per capita in the state	0.1359 [3.23]	0.1362 [3.24]	0.3208 [2.67]	0.3211 [2.67]
Previous year's t-bill return	-0.1332 [-5.44]	-0.1337 [-5.48]	-0.1294 [-1.83]	-0.1295 [-1.83]
Previous year's equity market return	0.0386 [0.15]	0.0235 [0.09]	1.4166 [1.98]	1.3983 [1.99]
Was ERISA's prudent man rule clarified?	1.1713 [6.45]	1.1830 [6.70]	1.6815 [3.32]	1.6948 [3.41]
State capital gains tax rate	-2.5838 [-0.91]		-5.0675 [-0.61]	
Federal capital gains tax rate	-3.4408 [-5.14]		-6.2439 [-3.37]	
Sum of the state and Federal capital gains tax rate		-3.3684 [-5.45]		-6.1480 [-3.61]
Overall R^2	0.425	0.425	0.188	0.425
p-value of χ^2-statistic	0.000	0.000	0.000	0.000
Number of observations	765	765	765	765

Table 5. Summary statistics for funds in database. The sample is all funds raised by independent venture organizations included in the Venture Economics Venture Intelligence database. The first panel indicates the completeness of the records of independent venture partnerships in the corrected database. The second panel presents summary information for each venture organization.

Panel A: completeness of records in corrected database	
Items in record	**Observations**
Month and year of closing and fund size	826
Year of closing and fund size	20
Month and year of closing: No size	428
Year of closing: No month or size	20
Neither closing date nor fund size	112

Panel B: Summary Information for each venture organization				
	Mean	**Median**	**Minimum**	**Maximum**
Number of funds raised	2.23	1	1	25
Total funds raised (millions of 1994 $)[a]	$126.46	$57.11	$0.46	$2,267.02
Closing date of first fund in sample[b]	3/82	7/83	1/63	12/92
Closing date of last fund in sample[b]	5/85	12/86	1/63	12/92

[a]This tabulation does not include venture organizations where the size of all funds cannot be determined. It does include, however, those venture organizations where the size of some funds cannot be determined.

[b]This tabulation does not include venture organizations where the closing date of all funds cannot be determined. It does include, however, those venture organizations where the closing date of some funds cannot be determined. Funds whose month of closing cannot be determined are regarded as closing in July.

Table 6. Venture capital funds by year. The sample is all funds raised by independent venture organizations included in the Venture Economics Venture Intelligence database. The table indicates the number of independent venture partnerships that closed each year, as well as the number which have information on the size of the fund. For those with size data, the distribution of total funds committed each year (in millions of 1994 dollars) is also tabulated.

			Size of funds (millions of 1994 $s)	
Year	**Funds closed**	**Funds with size data**	**Average**	**Sum**
1961	2	0		
1962	2	0		
1963	1	0		
1964	0	0		
1965	1	1	$41.53	$41.53
1966	1	0		
1967	2	0		
1968	12	0		
1969	16	6	72.95	437.72
1970	14	5	50.25	251.25
1971	13	5	61.32	306.62
1972	11	5	24.22	121.10
1973	13	3	36.47	109.39
1974	11	6	14.41	86.46
1975	11	0		
1976	14	3	38.18	113.51
1977	9	3	28.39	85.18
1978	23	14	30.51	427.09
1979	27	11	43.95	483.46
1980	57	26	47.92	1,245.93
1981	81	47	36.43	1,712.10
1982	98	51	40.96	2,088.79
1983	147	99	55.08	5,452.48
1984	150	106	45.65	4,839.34
1985	99	74	56.63	4,190.56
1986	86	61	72.58	4,427.82
1987	112	95	56.61	5,378.32
1988	78	66	56.33	3,717.95
1989	88	70	49.40	3,457.52
1990	50	36	69.64	2,507.02
1991	34	23	66.47	1,528.73
1992	31	30	67.03	2,010.82
Total	1294	846	$53.22	$45,021.73

Table 7. Regressions for individual venture organization fundraising. The sample is all funds raised by independent venture organizations included in the Venture Economics Venture Intelligence database. The dependent variables are a dummy variable that equals one if the venture organization raised a fund in that year and the size of funds raised in millions of 1994 dollars. Independent variables include number of years since the venture organization raised a previous venture fund, the age of the venture organization, the total amount of venture capital raised by the organization in the past ten years, the dollar value of equity held by the venture organization in firms taken public this year and in the previous year, the market value of all venture capital-backed firms issuing equity in the previous year (all in millions of 1994 dollars), the previous year's real growth in gross domestic product (GDP), the return on t-bills in the previous year, the previous year's CRSP value weighted stock market return, a dummy variable that equals one if the Department of Labor clarified the prudent man rule and allowed pension investment in venture capital (equals one for all years after 1978), and the highest marginal capital gains tax rate effective in that year. All regressions are Heckman two-stage models. [t-statistics are in brackets.]

	Dependent Variable			
	Model 1		Model 2	
Independent Variables	Was fund raised?	If so, logarithm of fund size (1994 $s)	Was fund raised?	If so, logarithm of fund size (1994 $s)
Years since raising last fund	-0.4560 [-15.84]	-21.17 [-7.55]	-0.4692 [-21.58]	-14.15 [-7.02]
Square of the number of years since raising last fund	0.0272 [11.94]	0.8710 [3.94]	0.0291 [16.27]	0.5293 [3.28]
Age of the venture organization (years)	0.0136 [2.79]	0.9820 [2.32]		
Total venture capital raised during previous ten years for venture organization (millions of 1994 $s)			0.0004 [2.14]	0.1670 [9.56]
Value of equity held in firms brought public this year (millions of 1994 $s)	0.0037 [3.30]	0.3326 [3.50]	0.0029 [2.46]	0.1124 [1.15]
Value of equity held in firms brought public in the previous year (millions of 1994 $s)	0.0091 [4.39]	1.0310 [6.11]	0.0058 [2.58]	0.3742 [2.07]
Total value of firms brought public in previous year by all venture capitalists (millions of 1994 $s)	1.3xE-06 [0.23]	-0.0006 [-1.60]	1.7xE-06 [0.34]	-0.0006 [-1.72]
Real GDP growth in the previous year	-0.0048 [-0.72]		0.0006 [0.08]	
T-bill return in previous year	0.0724 [3.84]		0.0759 [5.45]	
Return on the CRSP value weighted index in the previous year	0.0027 [2.37]		0.0036 [2.86]	
Capital gains tax rate	0.0018 [0.31]	-1.1650 [-3.50]	0.0021 [0.41]	-1.8156 [-5.50]
Was ERISA's prudent man rule clarified?	-0.0382 [-0.37]	8.3666 [0.96]	-0.0472 [-0.44]	-5.4530 [-0.66]
Constant	-0.6230 [-2.15]	-0.5752 [-0.04]	-0.6357 [-2.27]	28.99 [1.98]
Log Likelihood	-8159.3		-8197.4	
p-value of χ^2-statistic	0.000		0.000	
Number of observations	5573		5573	

Table 8. Fixed-effects regressions for individual venture organization fundraising. The sample is all funds raised by independent venture organizations included in the Venture Economics Venture Intelligence database. The dependent variables are a dummy variable that equals one if the venture organization raised a fund in that year and the logarithm of the size of funds raised in millions of 1994 dollars. Independent variables include number of years since the venture organization raised a previous venture fund, the age of the venture organization, the total amount of venture capital raised by the organization in the past ten years, the dollar value of equity held by the venture organization in firms taken public this year and in the previous year, the market value of all venture capital-backed firms issuing equity in the previous year (all in millions of 1994 dollars), the previous year's real growth in gross domestic product (GDP), the return on t-bills in the previous year, the previous year's CRSP value weighted stock market return, a dummy variable that equals one if the Department of Labor clarified the prudent man rule and allowed pension investment in venture capital (equals one for all years after 1978), and the highest marginal capital gains tax rate effective in that year. Dummy variables for each firm are also included to control for firm fixed-effects. Coefficients on the firm dummies are omitted. The regressions for whether the venture organization raised a fund or not are logit. The conditional regressions for size of the venture fund are ordinary least squares estimates. [t-statistics are in brackets.]

	Dependent Variable			
	Model 1		Model 2	
Independent Variables	***Logit*** Was fund raised?	***OLS*** If so, logarithm of fund size (1994 $s)	***Logit*** Was fund raised?	***OLS*** If so, logarithm of fund size (1994 $s)
Years since raising last fund	-1.1056 [-18.80]	-2.903 [-1.02]	-1.3034 [-22.83]	2.343 [0.89]
Square of the number of years since raising last fund	0.1069 [16.91]	0.1526 [0.54]	0.1141 [18.74]	-0.2100 [-0.79]
Age of the venture organization (years)	-0.2772 [-11.23]	4.8364 [3.18]		
Total venture capital raised during previous ten years for venture organization (millions of 1994 $s)			-0.0049 [-7.10]	0.1660 [6.41]
Value of equity held in firms brought public this year (millions of 1994 $s)	0.0049 [2.03]	0.0128 [0.10]	0.0056 [2.22]	-0.0764 [-0.59]
Value of equity held in firms brought public in the previous year (millions of 1994 $s)	0.0138 [3.06]	0.2905 [1.38]	0.213 [4.09]	-0.1417 [-0.65]
Total value of firms brought public in previous year (millions of 1994 $s)	4.1xE-06 [0.38]	-0.0001 [-0.21]	-5.0xE-06 [-0.48]	0.0004 [0.55]
Real GDP growth in the previous year	-0.0315 [-1.42]	-1.875 [-1.42]	-0.0037 [-0.16]	-2.012 [-1.57]
T-bill return in previous year	-0.0160 [-0.43]	-1.727 [-0.77]	0.1154 [3.33]	-1.782 [-0.93]
Return on the CRSP value weighted index in the previous year	0.0009 [0.28]	-0.1847 [-0.80]	0.0061 [1.94]	-0.1959 [-0.89]
Capital gains tax rate	0.0007 [0.06]	-1.153 [-1.92]	0.0039 [0.36]	-1.506 [-2.45]
Was ERISA's prudent man rule clarified?	2.047 [5.75]	0.7768 [0.04]	0.0967 [0.35]	10.22 [0.67]
Constant	1.434 [1.62]	127.15 [2.77]	1.155 [1.26]	127.60 [2.89]
Log Likelihood/ Adjusted R^2	-1903.6	0.212	-1939.5	0.252
p-value of χ^2/ F-statistic	0.000	0.000	0.000	0.000
Number of observations	5323	1117	5323	1117

Table 9. Summaries of venture capital commitments by stage focus. The sample is all funds raised by independent venture organizations included in the Venture Economics Venture Intelligence database.

	Funds that have a stated focus on early-stage firms	Funds that do not have a stated focus on early-stage firms	Significance of the difference between early and non-early
Size of the fund (millions of 1994 $)	$41.98 [$24.66]	$56.95 [$35.88]	0.000 [0.000]
Amount of venture capital raised by organization in previous funds	$92.20 [$39.54]	$87.58 [$26.64]	0.714 [0.000]
Organization age (years)	4.38 [3.08]	3.77 [0.58]	0.140 [0.002]
Date of fund closing	August 1985 [June 1985]	August 1983 [May 1984]	0.000 [0.000]
Fraction of funds raised on west coast	38.3%	30.3%	0.017
Fraction of funds raised on east coast	32.2%	43.6%	0.001

Table 10. Regressions for stage focus of the fund. The sample is all funds raised by independent venture organizations included in the Venture Economics Venture Intelligence database. The dependent variable is a dummy variable that equals one if the fund raised explicitly stated a focus on early-stage investments. Independent variables include the age of the venture organization, the total amount of venture capital raised by the organization in the past ten years in constant 1994 dollars, a dummy variable that equals one if the firm was located on the West Coast, a dummy variable that equals one if the Department of Labor clarified the prudent man rule and allowed pension investment in venture capital (equals one for all years after 1978), and the highest marginal capital gains tax rate effective in that year. All regressions are logit estimates. [t-statistics are in brackets.]

	Dependent Variable			
	Did the fund raise state a focus on early-stage investments?			
Size of the fund (millions of 1994 $s)	-0.0057 [-2.82]	-0.0035 [-1.40]		
Age of the venture organization	0.0118 [0.75]		0.0018 [0.13]	
Total venture capital raised during previous ten years for this venture organization		0.0247 [1.62]		-3.24xE-07 [-0.71]
Was the fund located on the West Coast?	0.4026 [2.35]	0.4619 [2.70]	0.2280 [1.44]	0.2786 [1.79]
Was ERISA's prudent man rule clarified?	0.7659 [1.78]	0.9025 [2.11]	1.829 [4.39]	1.871 [4.52]
Capital gains tax rate	0.0208 [1.36]	0.0247 [1.62]	0.0395 [2.70]	0.0404 [2.80]
Constant	-2.244 [-3.14]	-2.502 [-3.49]	-4.333 [-6.25]	-4.401 [-6.39]
Log Likelihood	-455.3	-461.9	-557.4	-571.8
p-value of χ^2 statistic	0.002	0.001	0.000	0.000
Number of observations	818	843	1236	1283

B. Money Chasing Deals?

The Impact of Fund Inflows on Private Equity Valuations[65]

Paul Gompers and Josh Lerner*

February 1999

We show that inflows of capital into venture funds increase the valuation of these funds' new investments into firms. This effect is robust to (i) the addition of controls for firm characteristics, public market valuations, and various alternative explanations, (ii) an examination of first differences, and (iii) the use of inflows into leveraged buyout funds as an instrumental variable. Interaction terms suggest that the impact of venture capital inflows on prices is greatest in states with the most venture capital activity. Changes in valuations do not appear related to the ultimate success of these firms. The findings are consistent with suggestions that competition for a limited number of attractive investments may be responsible for rising prices.

1. Introduction

One of the enduring questions in the finance literature is whether exogenous shifts in the demand for individual securities affect their valuations. The efficient market hypothesis implies, as Myron Scholes stated in 1972, that "the shares a firm sells are not unique works of art but rather abstract rights to an uncertain income stream for which close counterparts exist either directly or indirectly." Over the past decades, this assertion has inspired a variety of analyses. Examples include analyses of the impact on stock prices of inclusion in the Standard & Poors' 500 Index [Dhillon and Johnson, 1991; Harris and Gurel, 1986; Shleifer, 1986], the effects of eased restrictions on foreign investors on valuations in developing country stock markets [Henry, 1996; Kim and Singhal, 1996; Stulz, 1997], and the relationship between mutual fund purchases and stock market returns, both on an individual security [Wermers, 1999] and an aggregate level [Warther, 1995]. While the analyses are not without their controversial aspects, several suggest that capital inflows appear to have a real effect on valuations.

The bulk of these analyses have focused on the valuation of public securities. This focus is surprising since numerous practitioner accounts suggest that the relationship between asset prices and demand shifts

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is particularly pronounced in *private* markets. This paper examines these relationships in one such environment, the U.S. private equity market. As the capital under management in this asset class has grown from $4 billion in 1978 to $200 billion in 1998, observers have claimed that increasing capital inflows have led to higher security prices, or colloquially, "too much money chasing too few deals." [Three representative accounts over the decades are Noone and Rubel, 1970; Sahlman and Stevenson, 1986; and Asset Alternatives, 1996.] This paper seeks to understand how the pricing of investments in one portion of the private equity market, venture capital, is affected by inflows to funds.[66] One way in which our paper is differentiated from earlier studies on the impact of mutual fund inflows and developing market liberalizations on securities prices is that we can examine the impact of inflows in particular segments of the private equity industry—e.g., funds dedicated to specific geographic regions and investment stages—on the pricing of those particular types of transactions.

We proceed in two parts. First, we seek to document a relationship between commitments to venture capital funds and the valuation of new investments. Second, we explore the cause of this relationship. We examine whether this relation is driven by demand pressures, *i.e.*, more money committed to the venture industry driving up the valuation of investments, or alternatively by improvements in investment prospects (either due to increases in expected cash flows or a reduction in the riskiness of investments) leading to both higher valuations and greater venture commitments.

We employ a data set of over 4000 venture investments between 1987 and 1995 developed by the consulting firm VentureOne, as well as detailed information on capital inflows from two specialized information vendors. While studies of publicly traded securities can examine daily changes in prices, gaps of one to two years between refinancings of venture-backed firms are typical. A price index based purely on the changes in valuations between financings for the same company would therefore be incomplete and misleading. We consequently employ a hedonic approach, regressing the valuation of firms on their characteristics such as age, stage of development, and industry, as well as inflow of funds to the venture capital industry. We also control for public market valuations through industry portfolio valuations and industry book-to-market and earnings-to-price ratios.

We find a strong relation between the valuation of venture capital investments and capital inflows. While other variables also have significant explanatory power—for instance, the marginal impact of a doubling in public market values was a 15% to 35% increase in the valuation of private equity transactions—the inflows variable is significantly positive. A doubling of inflows into venture funds led to between a 7% and 21% increase in valuation levels. The results are robust to the use of a variety of specifications and control variables.

We undertake a variety of diagnostic analyses. These examine whether the relationship between inflows and pricing is an artifact of our inability to fully control for firm characteristics, shifts in the value of comparable public firms, or changes in the required return on such investments. Our first approach is to add a variety of control variables that address several alternative hypotheses (e.g., price changes in comparable public firms only affect private valuations with a delay). We also utilize industry book-to-market and earnings-to-price ratio to control for potential changes in market risk premia.

Second, we examine first differences. Many venture-backed firms receive multiple financing rounds, often at sharply divergent valuations. Using changes in the valuations and firm characteristics limits the impact of unobserved heterogeneity across firms. We also estimate two-stage regressions that control for

[66]In a related analysis, Kaplan and Stein [1993] examine the evolution of buyout pricing during the 1980s, a period that saw a considerable expansion of funds established to make equity investments in buyouts. They show that the valuation of 124 buyout transactions mirrored market-wide movements in earnings-price ratios. Once these movements were controlled for, there was no significant time trend.

the probability of refinancing. During periods of high inflows to venture funds, firms are more likely to be refinanced, but the impact of inflows on valuations remains positive.

Third, we employ an instrumental variables approach to control for omitted variable bias which may unduly inflate the significance of our measure of venture inflows. We identify a variable that we argue is related to shifts in commitments to the private equity industry, but otherwise is largely uncorrelated with the expected success of venture capital investments: inflows into leveraged buyout funds. This approach increases the significance of the inflow measure substantially.

Fourth, we examine the impact of capital inflows in different market segments. We argue that the effect of inflows should not be uniform. Consistent with these suggestions, interaction terms suggest that the impact of venture capital inflows on prices is greatest in states with the most venture capital activity. In a related analysis, we decompose inflows to venture capital funds by location or stated fund objective. The segmentation of valuations and inflows into region and investment focus effectively increases the number of independent observations that we have. The evidence suggests that the influx of capital into funds with a particular focus has a greater impact on the valuation of investments meeting those criteria.

In the final analysis, we examine whether increases in venture capital inflows and valuations simultaneously reflect improvements in the environment for young firms. We look at the ultimate success of venture-backed firms. We show that success rates—whether measured through the completion of an initial public offering or an acquisition at an attractive price—did not differ significantly between investments made during the early 1990s, a period of relatively low inflows and valuations, and those of the boom years of the late 1980s. While, as we discuss below, the interpretation of these results is not without ambiguities, the analysis may help allay concerns about simultaneous shifts in the supply of entrepreneurial opportunities. Overall, the evidence is most consistent with the demand pressure explanation.

The plan of this paper is as follows. In Section 2, we discuss some of the key institutional aspects of the venture capital industry. Theoretical considerations are taken up in Section 3. Section 4 describes the data set. The results are presented in the fifth section. The final section concludes the paper.

2. Background[67]

Entrepreneurs often develop ideas that require substantial capital to implement. Most entrepreneurs do not have sufficient funds to finance these projects themselves and must seek outside financing. Start-up companies that lack substantial tangible assets, expect several years of negative earnings, and have uncertain prospects are unlikely to receive bank loans or other debt financing. Venture capitalists finance these high-risk, potentially high-reward projects, purchasing equity stakes while the firms are still privately held. Venture capitalists have backed many high-technology companies, including Cisco Systems, Genentech, Intel, Microsoft, and Netscape, as well as a substantial number of service firms.

Whether the firm is in a high- or low-technology industry, venture capitalists are active investors. They monitor the progress of firms, sit on boards of directors, and mete out financing. Venture capitalists retain the right to appoint key managers and remove members of the entrepreneurial team. In addition, venture capitalists provide entrepreneurs with access to consultants, investment bankers, and lawyers. Typically, all funds that the firm needs are not provided at once: rather the funds are disbursed in a series of financing rounds based on the attainment of milestones. Venture capitalists typically exit their successful investments by taking them public. While they rarely sell their shares at the time of the initial public offering (IPO), they frequently sell the shares or distribute them to their investors within two years of going public.

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[67]This section is partially based on Gompers and Lerner [1996].

Inflows of capital to venture funds have been characterized by wide swings over the five decades since the formation of the first modern venture capital firm, American Research and Development, in 1946. Only a handful of other venture funds were established in the decade after its formation. The annual flow of money into new venture funds between 1946 and 1977 never exceeded a few hundred million dollars and was usually much less.

Funds flowing into the venture capital industry and the number of active venture organizations increased dramatically during the late 1970s and early 1980s. An important factor accounting for the increase in money flowing into the venture capital sector was the 1979 amendment to the "prudent man" rule governing pension fund investments as well as the lowering of capital gains tax rates in 1978. Prior to 1979, the Employee Retirement Income Security Act limited pension funds from investing substantial amounts of money into venture capital or other high-risk asset classes. The Department of Labor's clarification of the rule explicitly allowed pension managers to invest in high-risk assets including venture capital. In 1978, when $424 million was invested in new venture capital funds, individuals accounted for the largest share (32 percent). Pension funds supplied just 15 percent. Eight years later, when more than $4 billion was invested, pension funds accounted for more than half of all contributions.

During this period, the limited partnership emerged as the dominant organizational form. (Most early funds had been structured as publicly traded closed-end funds.) In a venture capital limited partnership, the venture capitalists are general partners and control the fund's activities. The investors serve as limited partners. Investors monitor the fund's progress, attend annual meetings, but cannot become involved in the fund's day-to-day management if they are to retain limited liability. Venture partnerships have pre-determined, finite lifetimes (usually ten years, though extensions are often allowed). Most venture organizations raise funds every two to five years. Partnerships have grown from 40 percent of the venture pool in 1980 to 80 percent in 1995.

The steady growth in commitments to the venture capital industry was reversed in the late 1980s. Returns on venture capital funds declined because of overinvestment in various industries and the entry of inexperienced venture capitalists. (Between 1978 and 1988, the number of active venture organizations increased four-fold.) As investors became disappointed with returns, they committed less capital to the industry: commitments (in inflation-adjusted dollars) dropped by 68% between 1987 and 1991. The recent activity in the IPO market and the exit of many inexperienced venture capitalists led to an increase in returns. New capital commitments rose again in response, increasing by more than 500% between 1991 and 1997.

3. Theoretical Considerations

This section examines two sets of predictions for the relationships between inflows to venture capital funds and valuations. First, we will explore the empirical implications of the view that financial markets are perfect. We will then consider the alternative suggestion, that exogenous increases in inflows into venture funds can affect valuations due to the segmentation of this market from other financial sectors.

Finance theory teaches that the value of a firm should be equal to the discounted value of its expected future cash flows. The value of a firm should increase if investors learn that its future profitability will be higher. Similarly, if they learn that the firm will be less risky than originally foreseen—*i.e.*, its cost of capital declines—the valuation should rise. Since close substitutes exist for virtually any asset, either directly or indirectly through combinations of securities, demand curves should be flat. The movement in equity market prices, whether of publicly or privately held firms, should be driven by changes in the expected cash flows or the firm's cost of capital.

If markets are perfect, inflows of money into venture capital funds should be unrelated to the valuations of private companies. While one might argue that an asset class such as venture capital is

different from the individual securities discussed by Scholes, Shleifer, and Harris and Gurel, the analogy to the literature on individual securities is not unreasonable. The capitalization of venture capital funds did not exceed one percent of that of public equity markets during the years under study, and was typically much smaller. Most venture-backed private firms have close substitutes among public firms. As long as the inflow of capital is exogenous—*i.e.*, unrelated to future expected returns on venture investments—then the price of private firms should not be affected because substitutes will always exist. Neither the firm's cost of capital nor its expected cash flows should change with the inflow of capital.

If the inflow of capital to venture funds is not exogenous, however, then the empirical patterns may be more complex. In particular, more favorable expected conditions for young high-technology companies may trigger both increases in valuations and growth in commitments to venture capital funds. In this case, prices paid for investments and venture inflows would increase simultaneously, even if there were no causal relationship between the two. We discuss below how we control for this possibility.

The alternative view is motivated by the possibility that the venture capital market is segmented from other asset classes. In this case, exogenous increases in venture capital commitments may have a dramatic effect on prices. Because partnership agreements typically require that venture funds invest almost exclusively in private companies, increases in the supply of venture capital may result in greater competition to finance companies and rising valuations. The increase in commitments to the venture industry may also have different effects on different segments of the private equity market. For example, if capital is raised by funds in a geographically concentrated area and if investment by these funds is localized, then competition should lead to greater price increases where the inflows of capital are greatest.[68]

4. The Data Set

The core information on venture investments, including the valuation data, comes from VentureOne. VentureOne, established in 1987, collects data on firms that have obtained venture capital financing. Firms that have received early-stage financing exclusively from individual investors, federally chartered Small Business Investment Companies, and corporate development groups are not included in the database.

The companies are initially identified from a wide variety of sources, including trade publications, company Web pages, and telephone contacts with venture investors. VentureOne then collects information about the businesses through interviews with venture capitalists and entrepreneurs. Among the data collected are the amount and valuation of the venture financings, and the industry, strategy, employment, and revenues of the firm. Data on the firms are updated and validated through monthly contacts with investors and firms.[69] VentureOne then markets the database to venture funds and corporate business development groups.

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[68]These industry and geographic patterns may be distinguished from those in the case where positive news about an industry's prospects leads to a simultaneous increase in inflows and valuations. The favorable news reflected in the higher public market prices and inflows would likely have symmetric effects on early- and later-stage companies as well as on firms in various geographic regions: better industry prospects would improve the expected cash flow of all firms in an industry, independent of their stage of development. It should also be acknowledged that various other factors should be related to the valuation of the private companies, whether or not inflows affect pricing. Earnings might be a useful indicator of firm value. Firm value may also be related to the company's sales, employment level, or age. Considerable uncertainty exists about private companies. Many are years away from the positive cash flows that investors value. Signals such as these can separate firms that are expected to be relatively more successful from others. We will use these as control variables in the regressions that follow.

[69]The valuations associated with the financing of private firms are typically not revealed in public documents and investors and entrepreneurs may consider this to be sensitive information. VentureOne seeks to overcome this reluctance by emphasizing that its database also helps firms obtain financing. In particular, firms can alert investors whether they intend to seek further private financing or intend to go public in upcoming months.

VentureOne officials suggest that two forms of selection bias may affect the completeness of their valuation data. First, in its initial years, neither the firm's data collection methodology nor its reputation in the industry was as established as today. Thus, it was less likely to obtain valuation data. Second, they are sometimes able to collect information about earlier financing rounds at the time a firm seeks refinancing. Consequently, the most recent data—which includes many firms that have not subsequently sought refinancing—may not be as complete as earlier years' data.

These claims are borne out through an examination of Table 1. Of the 7375 venture rounds identified by the firm between 1987 and 1995,[70] the valuations of the firm at the time of the financing can be calculated in 4069 cases (55%).[71] The share of observations with valuation data in the first three years of the sample, 45%, is significantly lower than in the period from 1990 through 1994 (61%). Consistent with the above discussion, the completeness of observations for 1995 is again lower (49%).

To help understand the impact of the missing data, we compared those rounds with and without valuation data. Table 2 summarizes these patterns. First, VentureOne has had the least success in obtaining financing data about start-up transactions. This is not surprising. In these cases the number of investors is typically very small and concerns about secrecy are the greatest. VentureOne has also been less successful in obtaining valuation data about firms not in the high-technology industries traditionally funded by venture capitalists, but rather in the amalgam referred to as "other industries."[72] VentureOne officials attribute this pattern to the firm's greater visibility among entrepreneurs and investors in high-technology industries. Similarly, reflecting the firm's California base, it has been more successful in obtaining information about firms based in the western United States. Finally, since the observations with valuation data are disproportionately in the years 1990 through 1994, these observations had higher average public equity values (the construction of these measures of valuation is described below[73]) and weaker inflows to venture capital funds than in the others.

We do not believe these omissions of valuation data introduce systematic biases in the analyses below. To address this concern, in unreported analyses we repeat the regressions reported in Table 6 through 8 using a Heckman sample selection approach: *i.e.*, we first estimate the probability that the VentureOne has been able to obtain information about the valuation in the financing round, and then seek to explain the determinants of the valuation. We find that this correction has little impact on the

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[70]The VentureOne database also includes a variety of other transactions including initial and follow-on public offerings by venture-backed firms, investments in leveraged buyouts and publicly traded firms by venture funds, and so forth. In tabulating venture capital rounds, we eliminate these transactions and only include equity investments by professional venture organizations in privately held firms.

[71]Throughout this paper, we will use what is known in the venture industry as the "pre-money" valuation: the product of the price paid per share in the financing round and the shares outstanding prior to the financing round. As discussed at length in Lerner [1994a], the pre-money valuation is more appropriate for hedonic pricing analyses. The pre-money valuation is independent of the amount invested in the firm during the current financing round. As Gompers [1995] discusses, the amount invested may vary with many considerations, including the fundraising environment. In calculating the valuation, VentureOne converts all preferred shares into common stock at the conversion ratios specified in the agreements. Warrants and options outstanding are included in the total, as long as their exercise price is below the price per share being paid in the financing round.

[72]The definitions of the investment stage, industry, and regional groupings used in this paper are given in the Appendix.

[73]The simple average of the earnings-price ratio for public firms in the 35 industries is negative because many industries have a number of very small firms with significant negative earnings which introduces a substantial skewness to the distribution of this ratio.

magnitude or the significance of the independent variables in the analyses of the determinants of valuations.[74]

Table 3 provides an overview of the patterns of valuations in the sample. Not surprisingly, more mature firms receive higher valuations, with the exception of the dramatically depressed valuations for firms undergoing re-starts (financial and product market restructurings). Semiconductor, data processing, and communications companies have on average the highest valuations, while industrial equipment and instrumentation companies have the lowest. Firms based in the western United States—particularly in California—appear to be priced at a premium.

We supplemented the VentureOne data in several ways. First, some firms in the VentureOne sample were missing either an assignment to one of the 103 VentureOne industry classes or information on the firm's start date. We examined a variety of reference sources to determine this information, including Corporate Technology Information Service's *Corporate Technology Directory* [1996], Dun's Marketing Services' *Million Dollar Directory* [1996], Gale Research's *Ward's Business Directory of U.S. Private and Public Companies* [1996], National Register Publishing Company's *Directory of Leading Private Companies* [1996], and a considerable number of state and industry business directories in the collections of Harvard Business School's Baker Library and the Boston Public Library. We also employed several electronic databases: the Company Intelligence and Database America compilations available through LEXIS's COMPANY/USPRIV library and the American Business Disk CD-ROM directory.

Second, until recently VentureOne has not archived employment and sales data on firms. Instead, they merely updated the database entries. We consequently use the reference sources cited above to determine firm's sales and employment at the end of the calendar year prior to each financing with valuation data. When we could not identify either sales or employment from these sources, we contacted the firms for this information (the VentureOne database provides the contact information for these firms). Each firm received a faxed letter. Non-respondents were contacted at least twice by telephone. The final two columns of Table 1 summarize the extent to which we succeeded in this process. In all, we were about to identify historical sales data for 61% of the observations with valuation data in the VentureOne database and employment data for 66%.

Third, we developed several measures of public market valuations at the beginning of the month or the quarter of each financing. Rather than employing an overall market index, we constructed industry indexes. We first associated each of the 103 VentureOne industry classes with a three-digit Standard Industrial Classification (SIC) code. To do this, we examined all firms in each VentureOne class that had gone public. We tabulated the primary three-digit SIC code that these firms had been assigned to at the time they went public in Securities Data Company's Corporate New Issues database. In most cases, the overwhelming majority of firms in each VentureOne class were assigned to a single three-digit SIC code. When no SIC code represented a majority, we also examined the distribution of the three-digit SIC codes of the active privately held firms listed in the *Corporate Technology Directory*. In cases that remained ambiguous, we consulted with VentureOne officials regarding their classification criteria. In some cases, multiple VentureOne classifications were assigned to the same three-digit SIC code: e.g., numerous classifications were matched to SIC code 737, "Computer and Data Processing Services."

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[74]These tabulations of completeness beg the question as to whether VentureOne captures the total number of venture rounds, or whether the denominator substantially understates the total number of financings. In recent years, the total number of financing rounds identified by VentureOne has been within 10% of the total identified by Venture Economics (which compiles this information using the annual reports of venture capital funds). Before 1990, however, the Venture Economics tabulations indicate a substantially larger number of rounds than VentureOne does. This may partially reflect the incompleteness of the early VentureOne data, but also reflects the tendency of the older Venture Economics entries to record a single venture as multiple financings [discussed in Lerner, 1995].

For each of the 35 three-digit SIC codes, we then identified all active companies that had a primary classification to that SIC code in Compustat. For each of these firms, we extracted their monthly returns, shares outstanding, and market price at the beginning of each month from the Center for Research in Security Prices database. From Compustat, we identified the net income during and shareholders' equity at the beginning of each quarter.

We used these variables to create two sets of valuation measures. First, we constructed monthly equal- and value-weighted industry stock price indexes for each VentureOne code. The hope is that these industry stock price indexes will be a measure of industry investment opportunity, *i.e.*, by including them in the regression we control for the portion of the increase in venture capital prices that is attributable to better investment opportunities. We included all firms in each three-digit industry with a return in that month. We rebalanced the portfolios on a monthly basis. We were concerned, however, that these public market indexes might not perfectly measure future investment opportunities in an industry. In particular, an industry stock price index could be higher in 1995 than in 1988 because of *(i)* increases in price levels in the economy as a whole, *(ii)* upward revisions by investors of the expected future cash flows for that particular industry, or *(iii)* a decrease in the systematic riskiness of the industry leading to declines in the industry cost of capital. Increases in expected future cash flows and decreases in systematic industry risk would both lead to higher industry prices (and private valuations) and increases in investment inflows without the inflows driving up the prices. We also controlled for price levels (using the Gross Domestic Product—GDP—deflator) to alleviate the concern that industry stock prices might just measure increases in nominal prices.

Second, we measured valuation levels using two "market multiples." Price-earnings and market-to-book ratios are frequently used by practitioners as an approximate, if inexact, measure of equity market values. These ratios may be better measures of future investment opportunity in an industry than the industry indexes are. For each of the public firms assigned to the 35 industries, we computed *(i)* the ratio of net income in the four previous quarters to the equity market value at the beginning of the quarter of the financing and *(ii)* the ratio of shareholders' equity to the market value of the equity at the beginning of the quarter. (If multiple classes of common and preferred stock were outstanding, we combined the value of all classes.) As discussed above in footnote eight, in many industries, numerous small firms with significant negative earnings introduced a substantial skewness to the distribution of these ratios. We consequently computed both the simple averages of these ratios as well as the averages weighted by equity market capitalization at the beginning of the quarter.

Finally, we tabulated the inflow of capital to funds devoted to investments in venture capital and leveraged buyout transactions. To do this, we employed the records of the consulting firm Asset Alternatives (the publisher of the newsletter *Private Equity Analyst*). Because financings display a strong seasonal pattern (many institutions defer making commitments of capital until the last quarter), we tabulated the total inflation-adjusted amount of funds raised in the previous four quarters.[75]

[75]The tabulation of venture capital raised by year (displayed in Table 4) differs from those presented in Gompers and Lerner [1996]. The latter tabulation was based on the records of Venture Economics whose methodology differs from that of Asset Alternatives in two ways. First, many funds raise capital through multiple closings. (In a closing, an investor or group of investors sign a contract that binds them to supply a set amount of capital to a private equity fund, and often provide a fraction of that capital immediately.) The Venture Economics database treats the total amount ultimately raised by the fund as having been raised on the date of the first closing; the Asset Alternatives database treats each closing as a separate event. Second, some private equity funds make investments into both venture capital and buyout transactions. While there does not appear to be a systemic pattern, Venture Economics and Asset Alternatives differ in how they classify some of the hybrid funds.

5. Empirical Analyses

Before examining the determinants of the valuations of venture investments econometrically, we present the basic patterns. Table 4 makes clear that the highest inflation-adjusted valuations between 1987 and 1995 were associated with the years 1987, 1994, and 1995. These were also the years with the greatest inflows to private equity funds (in constant dollars). The table also presents the average of the book-to-market ratios and inflation-adjusted equity indexes for 35 industries, whose construction is described above. (In both cases, we present the value-weighted averages.) Here, the correlation with the pricing of venture investments is less clear: the greatest public market valuations were confined to the final years of the sample.

We also present two graphical depictions of the pricing patterns. Figure 1 presents the average of the public market indexes and the private equity valuations on a quarter-by-quarter basis, as well as the annual inflow into venture funds. (For the sake of clarity, both the market indexes and the inflows are presented on a scale that is normalized to 1.00 in 1987.) Figure 2 presents the valuation of early- and later-stage investments on a biannual basis. The more dramatic rise of pricing levels for later-stage investments in both the first and last years of the sample is apparent.

A natural question is the extent to which the changes in valuations over time are driven by the changing mixture of firms being financed. The higher valuations in 1987, 1994, and 1995 may be a consequence of the fact that different firms may be funded during periods of rapid growth in commitments to venture funds. Venture capital organizations do not proportionately add partners as they increase capital under management [for a discussion and evidence, see Gompers and Lerner, 1996]. Meanwhile, the number of investments that each partner can oversee is typically quite limited. Each investment requires extensive due diligence, attendance at monthly board meetings, and frequent informal interactions. Consequently, venture funds that are rapidly growing tend to increase the average amount that they invest in each firm and shift from early- to later-stage investments, which can typically absorb more capital. This suggests the desirability of examining the share of firms being funded each year that were of the types that commanded high valuations. Examples would include firms with higher sales, those which are already profitable, and those in the semiconductor industry. (We will, of course, also control for these characteristics in the regression analyses that follow.)

Table 5 presents some univariate evidence in this regard:

- The relationship between sales and employment on the one hand and venture capital inflows on the other is economically and statistically insignificant. The correlation coefficient, for instance, between inflows and sales is only 0.006.

- Start-ups (which command the lowest valuations on average) actually comprise a greater percentage of the sample during periods with high inflows into venture capital funds, while the probability that firms in the sample are shipping products or profitable varies negatively with inflows. This is exactly the opposite pattern than we would have expected were the valuation pattern a consequence of the mixture of transactions.

- Of the highly valued industries, medical-related and data processing firms display a relationship between the probability of being funded and venture capital inflows that is statistically significant at the five percent confidence level. In one case, there are fewer of these transactions during years with the greatest venture capital inflows; in the other case, more.

Thus, the pattern of valuations over time does not appear to be determined by the changing mix of transactions. We must look elsewhere for an explanation of the time-series variation.

A. Basic Econometric Analysis

As the above analysis suggests, the econometric analysis of the valuation of venture capital investments poses estimation challenges somewhat different from traditional studies of the pricing of publicly traded assets. Most pricing studies examine changes in the prices of an essentially constant basket of securities (except, of course, for new offerings and delistings). This environment is quite different. The average time between refinancings in our sample—and hence price observations—is 16.4 months.

One approach would have been to examine only the changes in prices for firms that had a previous observed valuation. (This is reminiscent to the "matched model" approach employed in pricing analyses.) As Berndt and Griliches [1993] argue, this method can lead to misleading estimates. In particular, if the process through which new firms are valued is different from that in the refinancing of existing firms, this analysis may give a biased impression. For instance, in the pharmaceutical industry political pressures have often limited companies' abilities to raise the price of existing pharmaceutical products, but have had much less impact on the initial pricing of new drugs. Furthermore, this approach eliminates those companies that only receive one financing. It might be thought that these firms (which are typically the concerns that are liquidated or merged) differ systematically from the others.

Consequently, we examine the pricing pattern using a hedonic regression approach. This method, first developed by Frederick Waugh to examine the pricing of vegetables in Boston's Fanueil Hall in 1927, includes all price observations in a regression analysis. The analysis includes firms receiving their first or follow-on financings. The price is the dependent variable; the characteristics of the firm and the environment are the independent variables. The regression approach enables us to incorporate even those firms that received just one financing round.

An important assumption of hedonic pricing models, however, is that the researcher can either measure the factors that are important for determining the price of the firm or good or identify reasonable proxies for these measures. If the qualities that determine the price are not quantifiable or measurable, then the hedonic regression model will have little explanatory power. Alternatively, the omitted variables may introduce biases that lead to mistaken interpretations of the results.

Tables 6 and 7 present the basic analysis.[76] We employ an ordinary least squares (OLS) specification and a "log-log" framework: we regress the logarithm of the valuation on the dummy variables and the logarithms of the continuous, non-negative variables. The log-log specification makes sense because many of the factors should be multiplicative. For instance, an increase in public market values should lead to a greater dollar increase in the valuation of an already substantial firm than that of a smaller one. As opposed to Table 4, we employ the nominal value of the valuation, correcting for inflation through the addition of an independent variable with the GDP deflator.

We use a variety of independent variables. First, we employ dummy variables for the firm's industry, stage of development, and location. Second, we control for public market valuations of firms in the same industry. In Table 6, we include the value of corresponding equal- and value-weighted industry indexes (whose construction was described in the previous section) at the end of the month prior to the financing. In Table 7, we rerun the regressions using the value of the two "market multiples" (also described above) at the end of the quarter prior to the financing. Third, we employ venture capital inflows (in constant dollars) in the four quarters prior to the investment. Finally, we use the firm's age, employment, and

[76]The regressions in these and all other tables (with the exception of the Heckman sample selection regressions reported in the third and fourth columns of Table 10) employ t-statistics computed with heteroskedastistic-consistent standard errors [White, 1980]. Because in many cases there are several observations of the same firm (due to multiple financing rounds), the observations may not be independent. We address this issue in the final two paragraphs of this section.

sales. Because employment and sales data are missing in some cases, and the two measures are highly correlated with each other, we present regressions that do not use either variable and then ones that use each in turn.

Significantly higher valuations are associated with profitable firms. There is a monotonic relationship between stage of development and valuation. Start-ups and firms undergoing restructurings have lower valuations. These firms have considerably more uncertainty about whether they will ultimately be successful. Older and larger firms are associated with higher valuations than less developed firms. Greater age and size are also likely to be proxies for superior future prospects, so these results are not surprising.

The regressions also suggest that firms in the eastern and western United States are associated with higher valuations, as are those in the computer hardware, communications, medical, and semiconductor industries. The geographic patterns are not surprising: as many discussions have highlighted, firms situated in high-technology complexes enjoy a variety of benefits that may be reflected in the higher valuations. These include the presence of specialized intermediaries such as patent lawyers, an ample supply of the highly skilled employees that they require, and technological spillovers [for a general discussion, see Krugman, 1991].[77] We have no prior reason to believe any industry patterns should emerge, but they may reflect the greater expected future cash flows for firms in these industries.

Public market valuations have an uneven impact. When we employ the industry indexes in the regressions, the measures are consistently significant. A 10% increase in public market values is associated with a marginal increase in private equity valuations of between 1.5% and 3.5%. The coefficient on the average industry book-to-market ratio is, as expected, negative: an industry whose average book-to-market ratio is high has lower private equity valuations in the subsequent quarter. A common interpretation of high book-to-market ratios is an indication that the industry has lower future growth prospects. This variable is, however, only of borderline statistical significance. The earnings-to-price ratio of firms in the same industry at the end of the previous quarter is consistently insignificant, and its sign is opposite of what would be expected.[78]

Finally, inflows to venture capital funds are consistently related to the valuations of these funds' investments in private firms at statistically significant confidence levels. A 10% increase in venture inflows is associated with a marginal increase in valuations of between 0.7% and 2.1%. This result is consistent with the suggestion that demand pressures affect prices.[79]

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[77]Similar results appear when we employ dummy variables for the states with the greatest venture capital investment, as California and Massachusetts, or when we use the pool of venture funds based in each state at the beginning of 1987. It is also possible that the East and West Coast dummies proxy for intense competition for attractive investments. We discuss this alternative later.

[78]When we use the median earnings-price ratio in the industry, which may be less influenced by outliers, the coefficient takes on the expected negative sign but remains statistically insignificant. The results are also robust to the use of the inflation-adjusted valuation as the dependent variable. In this case, the industry stock index is also inflation adjusted.

[79]The magnitude and significance of the coefficient on venture capital inflows coefficient falls when employment is used as a control variable, but to a much less extent when sales is employed. This is puzzling given the low correlation between inflows and the employment of firms financed. It appears to reflect the fact that the firms in which the employment is known are not entirely representative of the sample as a whole. Furthermore, this may partially reflect the smaller sample size. Were we to have full data on employment of these firms, the coefficient would be likely to be more significant. In many of the regressions below, however, we continue to use both sales and employment as control variables as a check of the robustness of the relation between inflows and valuations.

One concern with these analyses is the potential impact of autocorrelation across the different financings of the same firm. While we control for heteroskedasticity, the estimates may still be biased if the residuals are correlated. We address this concern repeating the estimation of several of the regressions reported in Table 6, employing a Generalized Least Squares (GLS) methodology. This allows us to simultaneously control for first-order autocorrelation across the subsequent financings of the same firm and heteroskedasticity across the observations of the different firms [McCullagh and Nelder, 1989]. Unfortunately, the estimation methodology requires that we only employ observations where firms have had two or more financings with valuation data. As a result, we compare the standard errors in these regressions to those in heteroskedasticity-corrected regressions only using cases where there is more than one observation of each firm.

We compare the regressions using White's heteroskedasticity adjustment reported in Table 6 to the GLS regressions. (In making the comparison, we restrict the regressions to observations where the firm had two or more financings with valuation data). We find that the correction for first-order autocorrelation has little impact on the results. While the standard errors are generally (but not universally) higher, the effects are modest. Consider the leftmost regression in Table 6. The standard errors for the location dummy variables are 1.6% higher on average in the GLS regressions; those of the sector dummies, 0.1%. The standard error on the venture inflow measure is actually very slightly lower once the GLS correction is made. The results of the other regressions in Table 6 are similar: in each case, the average standard error increases by less than 10% when the GLS specification is substituted for the heteroskedasticity-adjusted OLS regressions (holding the sample in each case constant).

B. Using Control Variables to Assess Robustness

While we find a relationship between venture inflows and prices, specification errors may cause a spurious correlation. This section will seek to assess the robustness of our results. None of these adjustments appear to alter the basic patterns seen above, *i.e.*, venture inflows continue to have a large, positive effect on valuations.

One possibility is that additional factors not captured in the basic specification affect the value of the venture-backed firms. The firms used to construct the public market benchmarks, while matched by industry, differ systematically from the firms backed by venture capitalists in at least two ways: they are on average considerably larger and have already successfully accessed the public capital markets. A considerable literature [e.g., Fama and French, 1992] has shown that the stock market returns of small firms differ significantly from those of other concerns.

We address this concern by adding additional control variables to the basic specification. The first of these, as shown in the top panel of Table 8, is an index of the performance of small-capitalization stocks. We employ Ibbotson and Associates' monthly index of the total return on the two smallest deciles of firms traded on the New York and American Stock Exchanges. While this small-capitalization stock index has considerable explanatory power, the influx of funds into venture capital funds remains highly significant.

We also employ a variety of additional factors in unreported regressions. For instance, small private firms might be more sensitive to business cycles. To address this suggestion, we add indexes measuring the level of the GDP deflator, the real GDP, and the changes in these measures in the past three and six months. We also explore the impact of credit market conditions. Some firms may consider bank loans to be an alternative to venture financing. In situations where bank loans are more expensive or less available, entrepreneurs may be willing to settle for lower equity valuations, *i.e.*, pay a higher cost of equity capital. As a proxy for the premium that firms with weaker balance sheets must pay to borrow money, we employ the difference in the average yields of bonds rated by Moody's as "Aaa" and those rated "Baa." We also employ the number of small business failures and incorporations as tabulated by the

U.S. Small Business Administration's Office of Advocacy in order to capture changing conditions and expectations for small businesses as a whole. In each case, the impact of venture capital inflows on prices changes little in magnitude or significance.

A second possibility is that the pricing of investments by private equity firms reflects equity valuation levels in the public market, but only with a substantial lag. Because negotiations between venture investors and entrepreneurs can be protracted (e.g., if the venture investor needs to find a syndication partner before finalizing the transaction), the price of the investment might be tentatively agreed upon well before the date of the closing.

To address this possibility, we include the lagged industry price index as an additional independent variable. In alternative regressions, we employ the index value six, twelve, and eighteen months prior to the financing. (We report the results of the regression employing the index value twelve months prior to the financing in Panel B of Table 8.) These controls have little impact on the coefficient or the significance of the variable measuring the inflow of funds into the venture industry.

A third possibility is that prices may be affected by differences between first and later round investors. In particular, established venture groups tend to syndicate second and later venture rounds with less established investors [Lerner, 1994b]. These later rounds are associated with a substantial premium which partially reflects the fact that these later-round investors are rarely asked to join the board or provide other value-added services.[80]

To examine the possibility that these changing syndication patterns may affect valuations, we control for the round of venture investment. In the regression reported in Panel C of Table 8, we add a dummy variable indicating whether the transaction was a second or later venture round. While the dummy is strongly positive, suggesting that first-round investors are being compensated for their services by buying equity at lower prices, the measure of venture inflows remains positive and significant at least at the ten percent confidence level. Similar results appear when we employ additional independent variables to more finely indicate the round of venture investment.

C. First Difference Analysis

One persistent concern is that the analyses above cannot capture many of the firm-specific determinants of pricing. One way to address this concern is to undertake a first difference analysis. By examining the changes in valuation across venture rounds, we are able to minimize the distortionary effects of unobservable firm characteristics. This analysis is not without its limitations, due to the problems with "matched model" estimations discussed in the second paragraph of Section 5.A. Despite these limitations, the first-difference analysis can provide another check on the validity of the results.

In the first two columns of Table 9, we present the results of several OLS analyses. The observations are all venture rounds where the valuation is known in the current and subsequent financing rounds. The dependent variable is the difference between the logarithm of the valuation in the subsequent and current rounds (the same as the logarithm of the ratio). To maximize the sample size, we present the results from regressions that do not use employment or sales data. (The other results are similar.)

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[80]The reader may be confused about the addition of this control variable since we have already controlled for the firm's stage of development. While most firms receive their initial venture capital financing while still in the start-up or development stages, a significant minority receive their first venture financing after a number of years of operations. (For instance, Gompers [1995] reports that the average consumer products company was nearly six years old at the time of its first venture financing.) These older firms are likely to be shipping product or even to be profitable at the time of their initial financing round.

The greatest write-ups are associated with firms with the lowest valuations in the current rounds: *i.e.*, those in the start-up, development, or re-start phase. These are also the firms that are in greatest risk of not receiving another financing round. Many of the firms that disappear from the VentureOne database have either been terminated or else joined the ranks of the "living dead" (ongoing firms whose future growth prospects are so modest that they are not attractive candidates for an IPO or an acquisition). Thus, it is not surprising that the low-valued firms which receive a subsequent financing are associated with the greatest mark-ups: the very fact that they have been refinanced implies that they have made substantial progress. Neither is it surprising that firms encountering difficulty between the current and subsequent financing and undertaking a re-start round experience a dramatic drop in valuations. The change in price reflects new information that becomes available on these firms. Few clear patterns emerge by industry or location.

With respect to changes in the external environment, quite stark results emerge. Changes in public market valuations—whether measured using equal- or value-weighted indexes or (in unreported regressions) using the market multiples—have little impact on pricing. Changes in venture inflows, however, have a significant impact. The valuation of a firm financed in two consecutive years will increase by an additional eight percent if the venture capital inflow doubles in that period. The first differences results provide additional evidence that venture inflows could be driving up prices through greater investment competition.

The third and fourth columns of Table 9 presents Heckman sample selection analyses. Using each financing round as an observation, we estimate a two-equation system: the probability that there will be a subsequent financing round and, if so, the change in the valuation (again expressed as the difference between the logarithm of the valuation in the subsequent and current rounds). In the unreported first-stage probit analysis, several interesting patterns emerge. The probability of refinancing is higher during periods of large venture capital inflows.[81] This is broadly consistent with the impact of inflows on valuations. Those firms that are either already profitable (who typically go public thereafter) or undergoing a "re-start" (many of which are abandoned) are less likely to obtain subsequent venture financing. The probability of another venture financing falls when we examine firms financed at the end of the sample period, which reflects the fact that we do not observe their financings subsequent to the end of 1995. When we turn to the second-stage regressions, reported in the third and fourth columns of Table 9, the results are little changed from the OLS analysis. The coefficients of the variables explaining the change in valuations in the first two regressions, including the influx into venture capital, remain statistically significant in this analysis.

D. Decomposition of Price Movements

We next examine whether influxes of capital affect certain types of firms particularly strongly. We undertake two types of analyses. First, we examine whether the pricing of particular investments is especially sensitive to the influx of venture capital or public market values. We then examine whether the influxes into venture capital funds based in different locations and with particular investment foci have differential effects on the valuation of these types of transactions.

If the increase in valuations associated with periods of high venture inflows is caused by competition for investments between venture funds, then it is likely that the increase will not be uniform. First, while regions like Silicon Valley and Route 128 are characterized by a concentration of entrepreneurial ventures, the representation of venture capitalists is even more disproportionate. For instance, several hundred venture organizations have offices on Sand Hill Road near the Stanford University campus. Since many venture capitalists invest locally [see, for instance, Lerner, 1995], the regions with the most

[81]In a similar vein, Gompers [1995] shows that a one standard deviation increase in venture capital commitments leads to a two-month reduction in the time between venture financings.

venture funds are likely to experience the greatest competition for transactions. Second, as discussed above, the typical venture organization has seen an increase in capital managed per partner as fund size grew. Because of the pressure to deploy capital in larger transactions, we might expect that high venture inflows should disproportionately inflate the valuation of later-stage investments. Finally, because venture funds often invest locally and have (at least somewhat) well-defined mandates, the growth of venture funds of a particular type should have a disproportionate effect on valuations of that particular class of investment.

The first panel of Table 10 presents two representative regressions using interaction terms. Each uses the base specification—*i.e.*, without employment or sales, and measuring public market values with the equity indexes—though the results using the sales, employment, and market multiple variables are similar. In the reported regressions, we interact venture capital inflows and the public market indexes with a dummy variable indicating whether the firm is located in the two states with the largest venture pools (California or Massachusetts) or the financing is a later-stage transaction (a firm in the shipping or profitable stages at the time of the investment). We present the regressions employing an OLS specification and the equal- and value-weighted industry indexes. Rather than presenting the coefficients of all the variables, we present selected results.

Neither firm characteristic is significant when interacted with public market values: shifts in public market values appear to affect all transactions equally, regardless of stage or region. This supports the suggestion that the industry public market indexes measure the expected future profitability of the industry and hence affect the prospects of all firms. It is not the case that later-stage companies' "closeness" to the public markets causes greater sensitivity to public market price movements because of financing substitutability. Consistent with the discussion above, however, venture capital inflows appear to increase the valuations of California and Massachusetts firms more than other firms. The coefficient is also significant when we interact the venture capital inflow with the pool of venture capital based in the state. (This holds whether we measure the pool in absolute or *per capita* terms. In each case, we use the venture pool at the beginning of 1987 to avoid simultaneity problems.) The coefficient on the interaction between inflows and later-stage investments, while with the predicted positive sign, is statistically insignificant.

Panels B and C of Table 10 presents two representative analyses of how influxes of funds located in particular regions and focusing on certain stages affect the valuations of firms in those segments. The regressions examine the pricing of two particular classes of venture transactions: firms based in the eastern United States and later-stage investments. We compare how valuations change with the influx of funds based in that region or specializing in that class of investment, as well as with influxes to other types of funds.[82] By segmenting flows and valuations, we increase the number of independent observations that we can observe. In the former case, the coefficient is significantly greater on influxes into funds based in this particular region. (Similar results hold in several unreported analyses employing other geographic partitions.) A similar pattern emerges from the analysis of later-stage investments, but the difference is smaller in magnitude and statistically insignificant. This may partially reflect the imprecision with which funds report their investment targets: many venture organizations, which originally specialized in early-stage investments, continue to report such a focus long after they have raised substantial funds and shifted to later-stage transactions. (These firms may be reluctant to alert their limited partners, who might reasonably worry that the funds' returns will suffer during this transition.) This analysis provides at least some corroboration of the suggestion that the influx of funds influences the pricing of venture investments.

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[82]These classifications are from annual compilations of venture capital fundraising by Asset Alternatives and (in earlier years) Venture Economics.

E. Addressing Omitted Variable Bias

In settings where an important control variable is missing from a regression, omitted variable bias may lead to the coefficients of correlated independent variables being inflated [Judge, *et al.*, 1985]. This effect may be happening here. In particular, we may have omitted an important explanatory variable that would control for the changes in the quality of investments presented to venture capitalists. This omission may cause us to falsely impute significance to the measure of venture capital inflows. To address this problem, we employ an instrumental variable. We seek a variable that is correlated with the inflows to the venture capital industry, but otherwise unrelated to the venture capitalist's opportunity set.

The reason for worrying about this problem is as follows. The changes in opportunities facing venture capitalists are difficult to observe. Venture investors fund only a minute fraction of businesses begun each year, so it is unlikely that we could control for shifts in high-quality technological opportunities through the count of business starts. Public market indexes may inaccurately measure the shifts in value of private equity financed firms since the types of firms in each public index may be somewhat different from the corresponding firms attracting venture financing. (For instance, in certain years there were many private venture-backed Internet service providers and biotechnology firms, but few publicly traded ones.) If the shifts the number of opportunities is being measured inaccurately and inflows to the venture industry are correlated with these changes, our estimations may be misleading. In particular, inflows to the venture industry may be falsely identified as having a significant effect on pricing levels.

To address this problem, we employ the influx of capital to funds specializing in leveraged buyout (LBO) investments. This is an attractive instrument for two reasons. First, it is clear that inflows to venture and buyout funds are correlated: using annual data between 1980 and 1995, the correlation coefficient is 0.66 (with a p-value of 0.006). Like commitments to venture funds, influxes to buyout funds soared during the 1980s, dropped sharply in the early 1990s, and then recovered dramatically in the middle of the decade. These parallels reflect the manner in which institutional investors allocate their portfolios. Typically, a single group that specializes in "alternative investments" manages investments in venture and buyout funds. When the institution's investment policy committee increases the allocation to alternatives, the inflows to venture and buyout funds are both likely to increase.

Meanwhile, there has been relatively little correlation in recent years between the success of venture and buyout investments. Most successful investments by both venture and buyout investors are exited through IPOs. But in recent years, IPOs of firms backed by venture and buyout firms have not been strongly associated. In fact, between 1991 and 1995[83] the correlation between the number and dollar volume of venture- and buyout-backed IPOs has actually been *negative* (-0.24 and -0.19 respectively), though neither coefficient is significant at conventional confidence levels. Thus, LBO inflows appear to be little correlation with the success of venture investments. These two considerations suggest that this is an appropriate instrument for venture capital inflows.

Table 11 repeats the OLS analyses from Table 6, now estimated using the inflow into LBO funds as an instrumental variable. In each, the impact of venture inflows is equal or larger in magnitude and statistically more significant. The results are similar when the other reported OLS regressions are re-estimated. The instrumental variable estimations underscore the suggestions that capital inflows may be associated with greater competition for investments.

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[83] Venture-backed IPOs are compiled by both VentureOne and Venture Economics; but only Venture Economics tracks buyout offerings. They did not begin doing so on a systematic basis until the early 1990s.

F. Demand Pressure or Better Prospects

The analyses above have implicitly treated inflows to venture funds as exogenous: it has been used as an independent variable in the above regressions. This assumption may be questioned. In particular, inflows to venture funds may be a response to information that suggests that entrepreneurial firms are likely to do well in the future. This same information could lead venture capitalists to assign higher valuations to firms in which they invest. We could be implying a causal impact to fund inflows on the pricing of venture investments when both are actually correlated with the future prospects of these firms. We address this concern by examining the success rates of venture-backed firms over time.

Before addressing this issue empirically, our concerns can be at least partially assuaged by an examination of the determinants of inflows into venture funds. In another work [Gompers and Lerner, 1998], we examine the forces that affect fundraising by independent venture capital organizations between 1972 through 1995. We study both overall fundraising patterns and fundraising by individual venture organizations. These analyses underscore the importance of public policy changes on the overall fundraising patterns. The Department of Labor's clarification of the "prudent man" rule, which allowed pension funds to invest in venture capital, had a positive effect on commitments to the industry, as did decreases in the capital gains tax rate. While short-run performance (e.g., recent IPOs) influenced fundraising by individual organizations, shifts in public offering activity appeared to have little impact on overall fundraising activity. The importance of exogenous policy shifts in determining the inflow to venture funds at least partially addresses our concerns about using inflows as an independent variable.

Another way to address these concerns may be to examine the ultimate success of the firms funded by venture capitalists. If inflows to venture funds and high valuations are rational responses to information about the changing prospects of young firms, investments during these "hot" periods should be more successful. (If venture capitalists just simply made fewer investments during "cold" periods, this pattern would not occur. But in general, as a comparison of Tables 1 and 4 make clear, there is much greater variation in the inflows of capital to venture funds than in the number of firms receiving venture investments.)

This analysis faces two challenges. Ideally, we would compare the rate of return (perhaps adjusted to reflect the risks associated with the varying maturity of these firms) from the investments in various time periods. Unfortunately, many of the firms remain privately held, or else were acquired for an undisclosed price. Thus, we employ two proxies. The first of these is the percentage of firms that have been taken public (or filed to go public with the SEC). Successful IPOs are highly correlated with attractive returns: venture capitalists generate the bulk of their profits from firms that go public. A Venture Economics study [1988] finds that a $1 investment in a firm that goes public provides an average cash return of $1.95 in excess of the initial investment, with an average holding period of 4.2 years. The next best alternative, an investment in an acquired firm, yields a cash return of only 40 cents over a 3.7 year mean holding period. The second measure that we employ is the percentage of investments that either resulted in an IPO or were acquired for at least twice the valuation of that round. While VentureOne is not able to obtain the valuation for all acquired firms, it is able to do so for many of the larger (and hence more visible) transactions.[84]

A second concern is that many of these firms remained privately held at the time we assessed their status (March 1996). Some of these will ultimately be successful. As a result, we only examine the outcome of venture investments between 1987 and 1991. This may lead to a bias: the later years (e.g., 1990 to 1991) should have a lower share of companies reaching successful exits simply because they have had less time to mature to the point of being taken public or sold.

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[84]We also explore the robustness of the results to the use of other definitions of successful acquisitions, such as those five or ten times the valuation at the time of the venture financing. These alternative definitions have little impact on the results.

The results of this analysis are presented in Table 12. We compare the success of investments in the years with high influxes to venture funds with those in other years. The observations include the 1798 professional venture financings of privately held firms between January 1987 and December 1991 in the VentureOne database where VentureOne was able to determine the valuation of the financing round. In the first panel, we compare whether the firm had gone public (or had filed to go public) as of March 1996; in the second, we measure if the firm had gone public, filed to go public, or been acquired at more than twice the valuation of the original venture round as of March 1996. In each panel, we divide the observations in two ways: we compare financings in 1987 and 1988 to those between 1989 and 1991, and those made between 1987 and 1989 to those from 1990 and 1991.

In each case, we find that the probability of a successful exit is slightly higher in the earlier period with high inflows to venture funds. None of these differences, however, are statistically significant at conventional confidence levels. Because many of the firms funded in the later years were still quite immature in March 1996, we can expect that over time, the difference between the success rate of the two classes of investments will narrow. While as discussed above, the interpretation of these patterns is not unambiguous, they help allay fears that shifts in venture inflows and valuations were driven by changes in future prospects.

6. Conclusions

This paper revisits the question of whether flows of capital into an asset class affect the valuation of those assets and whether those changes in valuation reflect shifts in the demand for those securities or changes in future prospects. Unlike virtually every previous analysis, which focus on public markets, this analysis examines the U.S. private equity market, where practitioner accounts suggest these effects are particularly strong.

We have addressed two primary questions in this paper. First, the analysis shows that inflows to venture capital funds have had a substantial impact on the pricing of private equity investments. This effect is robust to the addition of a variety of variables to control for alternative hypotheses, an analysis of first differences, and the use of instrumental variables. Consistent with predictions, the impact of venture capital inflows on prices was greatest in states with the most venture capital activity and segments with the greatest growth in venture inflows. The increase in the probability of refinancing in the Heckman sample selection regressions during periods of high inflows is also broadly consistent with the valuation patterns.

Second, we show that the relation between increased fundraising and prices does not appear to be due to greater perceived investment prospects. The regulatory- and tax-driven nature of venture fundraising and the insignificant difference in success rates of investments in "hot" and "cold" fundraising periods suggest that demand pressure drives prices up during high inflow periods.

These findings have a variety of implications. First, the results suggest that examinations of the impact of fund inflows on valuations in other investment classes in which fund inflows fluctuate widely due to regulatory and tax factors would be fruitful. Real estate and developing country capital markets are two particular areas that may enhance our understanding of this phenomenon.

Second, the results raise a series of public policy questions. Several economists [e.g., Stiglitz, 1993] have expressed concerns about the destabilizing influence of shifts in foreign capital inflows ("hot money") on developing countries' equity markets. It may be that some of the same detrimental effects are at work here. The U.S. venture capital market is also characterized by highly variable capital inflows which affect not only the volume of investments but—as this paper has documented—the valuations of these transactions. Numerous industry observers have expressed concern about the impact of these shifts on the pace and direction of technological innovation. During periods with high inflows, venture capitalists' standards for funding firms are alleged to be lowered, only to be raised dramatically when

inflows decline. [For a discussion of the detrimental impacts of these cycles on both private and social welfare, see National Advisory Committee on Semiconductors, 1989.] A careful examination of the effects of financing patterns on the rate and pattern of innovation is a fertile area for future research.

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Appendix: Definition of Firm Categorizations

Definition of Investment Stages

Start-Up: Company with a skeletal business plan, product, or service development in preliminary stages.

Development: Product or service development is underway, but the company is not generating revenues from sales.

Beta: For companies specializing in information technology, the beta phase is when the product is being tested by a limited number of customers but not available for broad sales. For life sciences companies, beta is synonymous with a drug in human clinical trials or a device being tested.

Shipping: The product or service is being sold to customers and the company is deriving revenues from those sales, but expenses still exceed revenues.

Profitable: The company is selling products or services and the sales revenue yields a positive net income.

Re-Start: A recapitalization at a reduced valuation, accompanied by a substantial shift in the product or marketing focus.

Definition of Industry Groups

Data Processing: Firms whose primary lines-of-business are personal computing, minicomputers or workstations, mainframe computers, CAD/CAM/CAE systems, data storage, computer peripherals, memory systems, office automation, source data collection, multimedia devices, and computer networking devices.

Computer Software: Firms whose primary lines-of-business are compilers, assemblers, and systems, application, CAD/CAM/CAE/CASE, recreational and home, artificial intelligence, educational, and multimedia software.

Communications: Firms whose primary lines-of-business include modems, computer networking, fiber optics, microwave and satellite communications, telephone equipment, pocket paging, cellular phones, radar and defense systems, television equipment, teleconferencing, and television and radio broadcasting.

Consumer Electronics: Firms whose primary lines-of-business include audio and video consumer equipment, automotive electronics, and consumer electronic games.

Industrial Equipment: Firms whose primary lines-of-business include energy management and process control systems, robotics, lasers, and inspection, integrated circuit production and oil-and-gas drilling equipment.

Medical: Firms whose primary lines-of-business include biotechnology, pharmaceuticals, diagnostic imaging, patient monitoring, medical devices, medical lab instruments, hospital equipment, medical supplies, retail medicine, hospital management, medical data processing, and medical lab services.

Instrumentation: Firms whose primary line-of-business are analog, digital and analytical instruments, as well as analytical and test equipment.

Components: Firms whose primary lines-of-business include connectors, displays, power supplies, microwave components, switches and relays, transducers and sensors, semiconductor packaging, and circuit boards.

Semiconductor: Firms whose primary lines-of-business are discrete semiconductors, semiconductor memories, microprocessors, optoelectronics, and application specific, linear/analog, digital logic and gallium arsenide integrated circuits.

Other: Firms whose primary lines-of-business include retailing, construction, information services, financial services and institutions, data management services, publications, education, transportation, services, energy, agriculture, textiles, remediation and recycling, and environmental equipment.

Definition of Regions

Eastern States: Firms whose headquarters are located in Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and West Virginia.

Western States: Firms whose headquarters are located in Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming.

Source: Compiled from VentureOne [1996].

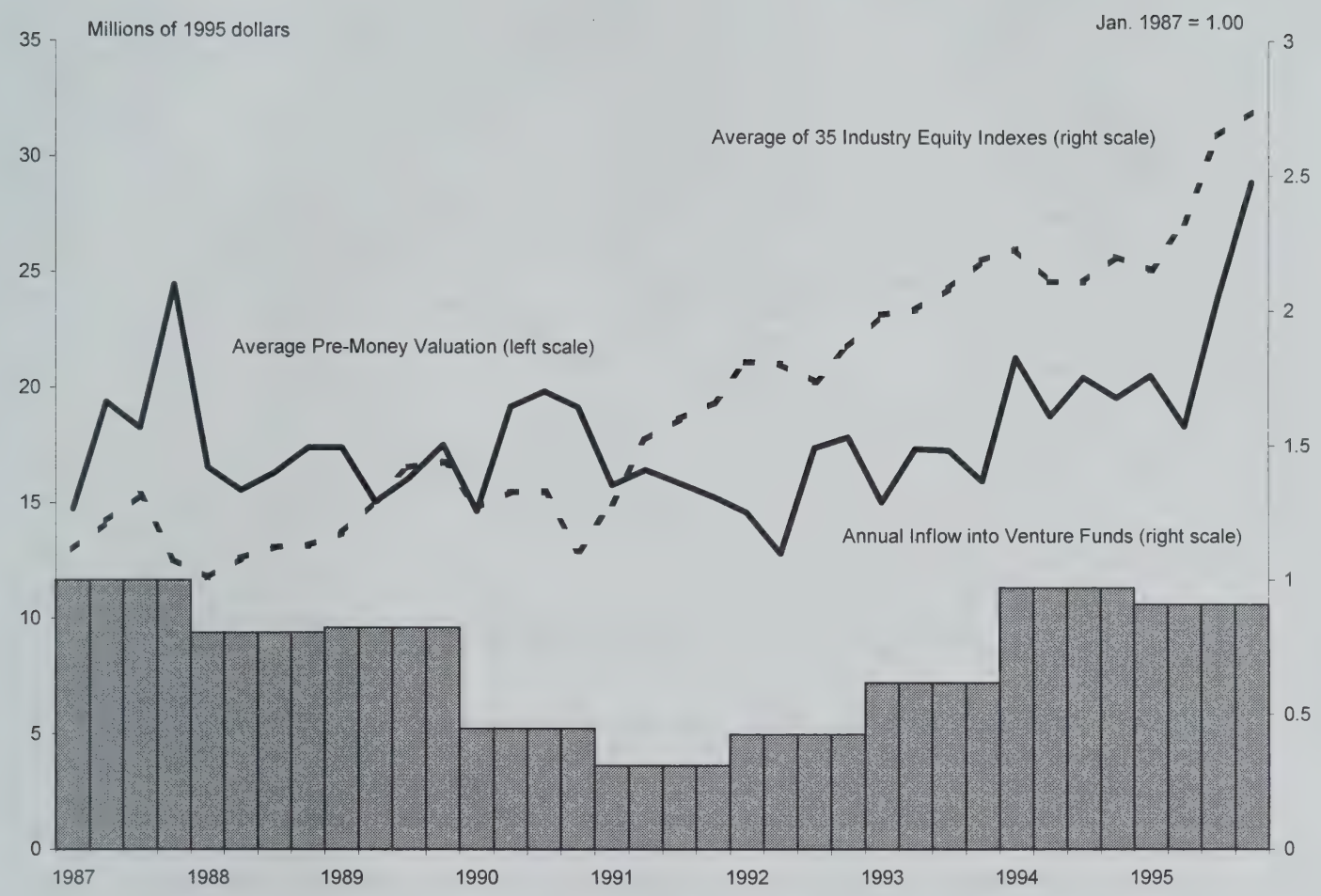

Figure 1. Pre-money valuations of financing rounds, average public market equity values, and inflows into the venture capital industry. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database where VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round, and is expressed in millions of 1995 dollars. The figure presents the mean pre-money valuation for each quarter, the unweighted average of the 35 value-weighted industry stock indexes used to control for the public market valuations (with January 1, 1987 normalized as 1.00 for each index and with an adjustment for inflation), and the total annual inflow to the venture capital industry (with 1987 normalized as 1.00).

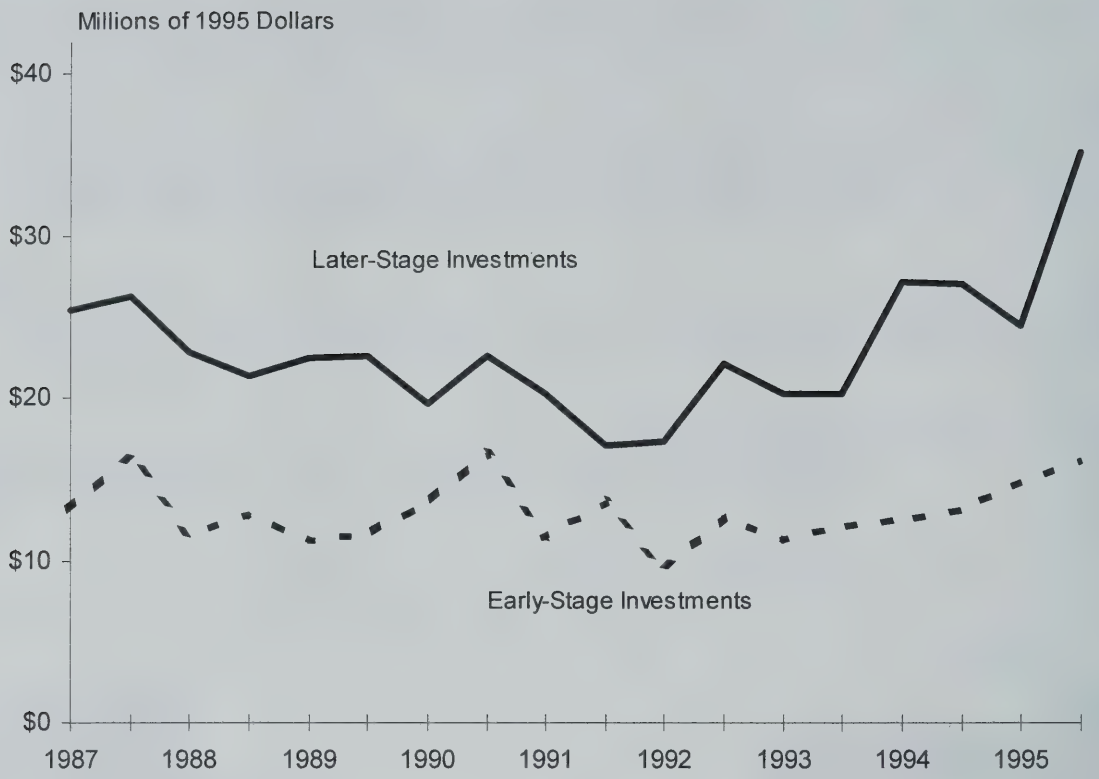

Figure 2. Pre-money valuations of later- and early-stage financing rounds. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database where VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round, and is expressed in millions of 1995 dollars. The figure presents the mean pre-money valuation for firms in the shipping or profitable stages, as well as those in all other stages, in each half-year period.

Table 1. Number of observations, by year. The table indicates the number of professional venture financings of privately held firms in the VentureOne database, as well as the number and percentage with valuation data. Of the rounds with valuation data, the table also displays the number and percentage for which we obtained sales and employment data for the beginning of the year of the financing.

				Of Rounds with Valuation Data...			
Year	*Number of Financing Rounds*	*Rounds with Valuation Data*	*Percentage with Valuation Data*	*Rounds with Sales Data*	*Percentage with Sales Data*	*Rounds with Employment Data*	*Rounds with Employment Data*
1987	693	255	36.8%	166	65.1%	191	74.9%
1988	634	314	49.5%	207	65.9%	221	70.4%
1989	751	369	49.1%	262	71.0%	276	74.8%
1990	797	420	52.7%	269	64.0%	275	65.5%
1991	785	440	56.1%	283	64.3%	297	67.5%
1992	941	626	66.5%	334	53.4%	332	53.0%
1993	952	647	68.0%	364	56.3%	358	55.3%
1994	955	570	59.7%	349	61.2%	428	75.1%
1995	867	428	49.4%	268	62.6%	315	73.6%
All Years	7375	4069	55.2%	2502	61.5%	2693	66.2%

Table 2. Comparisons of financing rounds with and without valuation data. The sample consists of 7375 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database. The table summarizes the characteristics of the 4069 financing rounds in the sample for which VentureOne was able to determine the valuation of the financing round, and the 3306 where VentureOne was not able to do so. The table also presents the p-values from t- and χ^2-tests of the null hypothesis that these two populations are identical. Industry public equity indexes are normalized to 1.00 on January 1, 1987.

	Rounds with Valuation Data	*Rounds without Valuation Data*	*p-Value from Test of Equality*
Stage of Firm at Time of Round:			
Firm is in Start-Up Stage?	9%	18%	0.000
Firm is in Development Stage?	31%	28%	0.001
Firm is in Beta Stage?	5%	2%	0.000
Firm is in Shipping Stage?	43%	44%	0.734
Firm is in Profitable Stage?	8%	8%	0.184
Firm is in Restart Stage?	2%	1%	0.008
Industry of Firm:			
Firm is in Data Processing Industry?	9%	8%	0.256
Firm is in Computer Software Industry?	17%	17%	0.450
Firm is in Communications Industry?	16%	13%	0.001
Firm is in Consumer Electronics Industry?	1%	1%	0.133
Firm is in Industrial Equipment Industry?	4%	4%	0.780
Firm is in Medical Industry?	31%	27%	0.000
Firm is in Instrumentation Industry?	2%	2%	0.562
Firm is in Components Industry?	3%	3%	0.651
Firm is in Semiconductor Industry?	4%	3%	0.008
Firm is in Other Industry?	13%	22%	0.000
Location of Firm:			
Firm is Based in Eastern States?	24%	28%	0.000
Firm is Based in Western States?	57%	50%	0.000
Firm is Based Elsewhere?	19%	22%	0.000
Time and Other Characteristics:			
Date of Financing	January 1992	June 1991	0.000
Value-Weighted Industry Public Equity Index at Beginning of Month of Financing	2.31	2.19	0.000
Equal-Weighted Industry Public Equity Index at Beginning of Month of Financing	2.53	2.26	0.000
Value-Weighted Industry Book-to-Market Ratio at Beginning of Quarter of Financing	0.37	0.39	0.000
Equal-Weighted Industry Book-to-Market Ratio at Beginning of Quarter of Financing	0.80	0.70	0.155
Value-Weighted Industry Earnings-to-Price Ratio at Beginning of Quarter of Financing	0.03	0.03	0.924
Equal-Weighted Industry Earnings-to-Price Ratio at Beginning of Quarter of Financing	-0.15	-0.15	0.847
Age of Firm (years)	4.0	4.1	0.262
Venture Capital Inflow in Prior Four Quarters (millions of 1995 dollars)	3165	3429	0.000

Table 3. Pre-money valuations of financing rounds, by firm characteristic. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round, and is expressed in millions of 1995 dollars. The table presents the mean and standard error of the pre-money valuation for each category, as well as the number of observations in each category.

	Pre-Money Valuation		*Number of Observations*
	Mean	*Standard Error*	
Stage of Firm at Time of Round:			
Firm is in Start-Up Stage?	2.7	0.1	366
Firm is in Development Stage?	14.3	0.6	1231
Firm is in Beta Stage?	21.1	1.6	217
Firm is in Shipping Stage?	20.1	0.6	1706
Firm is in Profitable Stage?	33.4	2.0	332
Firm is in Restart Stage?	3.9	0.5	73
Industry of Firm:			
Firm is in Data Processing Industry?	20.0	1.3	376
Firm is in Computer Software Industry?	14.4	0.8	706
Firm is in Communications Industry?	19.0	1.0	636
Firm is in Consumer Electronics Industry?	16.2	2.4	44
Firm is in Industrial Equipment Industry?	12.9	1.2	164
Firm is in Medical Industry?	17.8	0.7	1260
Firm is in Instrumentation Industry?	13.9	1.5	63
Firm is in Components Industry?	15.5	1.7	112
Firm is in Semiconductor Industry?	31.5	2.8	169
Firm is in Other Industry?	15.9	1.2	528
Location of Firm:			
Firm is Based in Eastern States?	16.0	0.7	983
Firm is Based in Western States?	19.1	0.5	2321
Firm is Based Elsewhere?	15.1	0.8	765

Table 4. Pre-money valuations of financing rounds, by year. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round, and is expressed in millions of 1995 dollars. The table presents the mean and standard error of the pre-money valuation for each year, as well as the inflow into the venture capital industry in that year (again in millions of 1995 dollars), the mean level of the 35 value-weighted industry stock indexes used to control for the public market valuations of firms in the sample (January 1, 1987 is normalized as 1.00 for each index and with an adjustment for inflation), and the mean level of the book-to-market ratio for the 35 industries (each industry ratio measure is the market value-weighted average of each active firm).

	Pre-Money Valuation		*Inflow into*	*Average of*	*Average of*
		Standard	*Venture*	*Value-Weighted*	*Book-to-*
Year	*Mean*	*Error*	*Industry*	*Indexes*	*Market Ratio*
1987	19.0	1.6	4969	1.18	0.50
1988	16.5	1.2	3995	1.09	0.54
1989	16.6	1.1	4082	1.33	0.54
1990	18.0	1.2	2221	1.25	0.49
1991	15.8	1.0	1542	1.51	0.58
1992	15.8	1.0	2108	1.80	0.49
1993	16.4	0.8	3065	2.06	0.43
1994	20.1	1.1	4825	2.16	0.38
1995	20.9	1.4	4517	2.47	0.41

Table 5. Characteristics of the sample firms receiving venture financing, by year. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The table summarizes the mean characteristics of the firms financed in each year included in the sample, as well as the correlation coefficient between these measures and the inflow into venture capital funds in the four quarters prior to the financing (in millions of 1995 dollars) and the p-value of the test of the null hypothesis that the correlation coefficient equals zero. Sales (in millions of 1995 dollars) and employment are at the beginning of the year of the financing.

Year	*Firm Sales*	*Firm Employment*	*Firm is in Start-Up Stage?*	*Firm is in Shipping Stage?*	*Firm is in Profitable Stage?*	*Firm is in Data Processing Industry?*	*Firm is in Communications Industry?*	*Firm is in Medical Industry?*	*Firm is in Semiconductor Industry?*
1987	10.9	90.0	13%	35%	4%	20%	13%	20%	5%
1988	9.6	79.3	17	37	6	21	14	21	7
1989	9.4	79.5	11	38	8	14	15	24	5
1990	7.2	66.1	6	47	5	12	16	26	6
1991	8.1	59.6	6	47	7	11	15	32	4
1992	7.8	67.0	7	45	8	6	14	36	3
1993	7.5	78.7	9	42	13	4	16	36	3
1994	5.7	57.8	8	42	9	5	17	34	3
1995	7.7	77.7	8	38	7	4	18	35	3
Corr. Coeff.	0.006	0.016	0.055	-0.059	-0.065	0.044	0.002	-0.056	0.022
p-Value	0.763	0.398	0.000	0.000	0.000	0.000	0.847	0.000	0.064

Table 6. Ordinary least square regression analyses of pre-money valuations of financing rounds. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round. The logarithm of the pre-money valuation, expressed in millions of current dollars, is used as the dependent variable. The independent variables include dummy variables controlling for the firm's status, industry, and location, and the logarithms of the firm's age (in years), of sales (in millions of 1995 dollars) and employment at the beginning of the year of the financing, of two indexes for the public market valuations of publicly traded firms in the same industry as the firm at the beginning of the month of the financing (with January 1, 1987 normalized as 1.00 for each index), and of the inflow into venture capital funds in the four quarters prior to the financing (in millions of 1995 dollars). Absolute heteroskedastistic-consistent t-statistics in brackets.

Independent Variables	*No Firm Size Measure*		*Using Firm's Sales*		*Using Firm's Employment*	
Stage of Firm:						
Firm is in Start-Up Stage?	-0.85 [6.67]	-0.87 [6.77]	-0.89 [5.35]	-0.90 [5.42]	-0.76 [5.35]	-0.77 [5.45]
Firm is in Development Stage?	-0.14 [1.11]	-0.16 [1.26]	-0.08 [0.52]	-0.11 [0.65]	-0.02 [0.16]	-0.05 [0.37]
Firm is in Beta Stage?	0.13 [0.96]	0.10 [0.75]	0.22 [1.26]	0.18 [1.02]	0.25 [1.62]	0.18 [1.20]
Firm is in Shipping Stage?	0.16 [1.37]	0.15 [1.23]	0.18 [1.16]	0.15 [0.95]	0.19 [1.47]	0.14 [1.12]
Firm is in Profitable Stage?	0.52 [3.98]	0.50 [3.83]	0.46 [2.80]	0.41 [2.49]	0.45 [3.17]	0.38 [2.70]
Firm is in Restart Stage?	-1.22 [8.66]	-1.25 [8.82]	-1.30 [7.71]	-1.35 [7.98]	-1.28 [8.49]	-1.35 [8.98]
Industry of Firm:						
Firm is in Data Processing Industry?	0.32 [3.64]	0.27 [2.99]	0.27 [2.37]	0.17 [1.48]	0.35 [3.35]	0.24 [2.36]
Firm is in Computer Software Industry?	-0.04 [0.51]	-0.02 [0.26]	-0.09 [1.04]	-0.07 [0.80]	-0.04 [0.56]	-0.02 [0.19]
Firm is in Communications Industry?	0.34 [4.76]	0.29 [3.98]	0.28 [3.14]	0.19 [2.05]	0.34 [4.13]	0.23 [2.83]
Firm is in Consumer Electronics Industry?	0.25 [1.47]	0.25 [1.48]	0.27 [1.48]	0.26 [1.46]	0.23 [1.56]	0.22 [1.58]
Firm is in Industrial Equipment Industry?	-0.21 [2.01]	-0.24 [2.29]	-0.23 [1.72]	-0.28 [2.13]	-0.18 [1.49]	-0.23 [1.91]
Firm is in Medical Industry?	0.39 [5.86]	0.37 [5.38]	0.43 [4.89]	0.37 [4.04]	0.46 [5.91]	0.38 [4.69]
Firm is in Instrumentation Industry?	0.01 [0.13]	-0.02 [0.13]	0.04 [0.32]	-0.01 [0.08]	0.09 [0.76]	0.04 [0.29]
Firm is in Components Industry?	-0.04 [0.38]	-0.05 [0.49]	-0.06 [0.49]	-0.08 [0.66]	-0.07 [0.54]	-0.08 [0.66]
Firm is in Semiconductor Industry?	0.60 [5.55]	0.60 [5.48]	0.45 [3.74]	0.44 [3.58]	0.49 [4.56]	0.49 [4.46]
Location and Other Characteristics:						
Firm is Based in Eastern States?	0.10 [1.92]	0.09 [1.78]	0.17 [2.62]	0.15 [2.42]	0.16 [2.77]	0.15 [2.54]
Firm is Based in Western States?	0.30 [6.48]	0.29 [6.39]	0.33 [5.72]	0.33 [5.61]	0.32 [5.97]	0.32 [5.90]
Log of Firm Age (in years)	0.43 [13.90]	0.43 [13.90]	0.30 [7.11]	0.30 [7.04]	0.19 [4.55]	0.18 [4.27]
Log of Firm Sales			0.19 [7.44]	0.20 [7.68]		
Log of Firm Employment					0.27 [13.73]	0.30 [14.31]
Log of Value-Weighted Industry Index	0.16 [4.21]		0.27 [5.20]		0.31 [6.42]	
Log of Equal-Weighted Industry Index		0.15 [4.17]		0.26 [5.61]		0.35 [7.93]
Log of Inflow of Venture Capital	0.18 [4.94]	0.19 [5.20]	0.14 [3.10]	0.16 [3.46]	0.07 [1.67]	0.09 [2.03]
Constant	-0.19 [0.58]	-0.24 [0.73]	-0.06 [0.14]	-0.16 [0.37]	-0.11 [0.27]	-0.26 [0.65]
R^2	0.32	0.32	0.34	0.34	0.38	0.38
F-statistic	98.94	98.38	69.47	70.80	76.33	76.39
p-Value	0.000	0.000	0.000	0.000	0.000	0.000
Number of Observations	3896	3896	2433	2433	2622	2622

Table 7. Ordinary least squares regression analyses of pre-money valuations of financing rounds, with alternative measure of public market valuations. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round. The logarithm of the pre-money valuation, expressed in millions of current dollars, is used as the dependent variable. The independent variables include dummy variables controlling for the firm's status, industry, and location, and the logarithms of the value-weighted and unweighted average ratios of book-to-market equity value and earnings-to-market equity value of publicly traded firms in the same industry as the firm, of the Gross Domestic Product deflator at the beginning of the quarter of the financing, of the firm's age (in years) at the beginning of the year of the financing, of the firm's sales (in millions of 1995 dollars) and employment at the beginning of the year of the financing, and of the inflow into venture capital funds in the four quarters prior to the financing (in millions of 1995 dollars). Absolute heteroskedastistic-consistent t-statistics in brackets.

Independent Variables	**Using Book to Market**		**Using Earnings to Value**	
	Value-Weighted	*Equal-Weighted*	*Value-Weighted*	*Equal-Weighted*
Stage of Firm:				
Firm is in Start-Up Stage?	-0.97 [5.76]	-0.98 [5.78]	-0.87 [6.05]	-0.87 [6.07]
Firm is in Development Stage?	-0.18 [1.07]	-0.18 [1.08]	-0.15 [1.11]	-0.16 [1.13]
Firm is in Beta Stage?	0.09 [0.51]	0.10 [0.56]	0.06 [0.37]	0.06 [0.37]
Firm is in Shipping Stage?	0.07 [0.42]	0.07 [0.47]	0.14 [0.27]	0.04 [0.27]
Firm is in Profitable Stage?	0.33 [1.91]	0.33 [1.95]	0.27 [1.81]	0.27 [1.82]
Firm is in Restart Stage?	-1.43 [8.19]	-1.41 [8.05]	-1.45 [9.26]	-1.45 [9.26]
Industry of Firm:				
Firm is in Data Processing Industry?	0.23 [1.93]	0.28 [2.29]	0.31 [3.01]	0.31 [3.00]
Firm is in Computer Software Industry?	0.01 [0.08]	-0.03 [0.30]	0.08 [1.05]	0.08 [1.06]
Firm is in Communications Industry?	0.24 [2.68]	0.30 [3.00]	30 [3.66]	0.30 [3.68]
Firm is in Consumer Electronics Industry?	0.32 [1.79]	0.38 [2.07]	0.29 [2.05]	0.29 [2.05]
Firm is in Industrial Equipment Industry?	-0.21 [1.57]	-0.15 [1.04]	-0.14 [1.18]	-0.14 [1.18]
Firm is in Medical Industry?	0.48 [5.50]	0.46 [5.27]	0.52 [6.70]	0.52 [6.65]
Firm is in Instrumentation Industry?	0.07 [0.54]	0.11 [0.75]	0.13 [1.09]	0.13 [1.08]
Firm is in Components Industry?	-0.03 [0.25]	0.01 [0.08]	-0.02 [0.18]	-0.03 [0.22]
Firm is in Semiconductor Industry?	0.46 [3.77]	0.49 [3.95]	0.51 [4.64]	0.50 [4.57]
Location and Other Characteristics:				
Firm is Based in Eastern States?	0.16 [2.55]	0.16 [2.46]	0.16 [2.66]	0.16 [2.70]
Firm is Based in Western States?	0.33 [5.69]	0.33 [5.68]	0.32 [5.95]	0.32 [6.00]
Log of Firm Age (in years)	0.28 [6.63]	0.28 [6.59]	0.16 [3.80]	0.16 [3.84]
Log of Firm Sales	0.21 [7.78]	1.84 [7.85]		
Log of Firm Employment			0.30 [14.02]	0.30 [14.00]
Log of Gross Domestic Product Deflator	1.96 [5.92]	1.84 [5.44]	2.48 [8.05]	2.53 [8.05]
Log of Equal-Weighted Industry Book-to-Market Ratio	-0.004 [1.27]			
Log of Value-Weighted Industry Book-to-Market Ratio		-0.36 [1.80]		
Log of Equal-Weighted Industry Earnings-to-Market Value Ratio			0.01 [0.43]	
Log of Value-Weighted Industry Earnings-to-Market Value Ratio				0.54 [0.82]
Log of Inflow of Venture Capital	0.20 [4.31]	0.19 [4.06]	0.14 [3.07]	0.13 [2.92]
Constant	-9.62 [5.74]	-8.84 [5.11]	-12.18 [7.92]	-12.40 [7.93]
R^2	0.34	0.34	0.38	0.38
F-statistic	68.69	68.75	74.62	75.15
p-Value	0.000	0.000	0.000	0.000
Number of Observations	2433	2433	2622	2622

Table 8. Ordinary least squares regression analyses of pre-money valuations of financing rounds, with controls for additional hypotheses. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round. The logarithm of the pre-money valuation, expressed in millions of current dollars, is used as the dependent variable. The independent variables in all regressions include dummy variables controlling for the firm's status, industry, and location, and the logarithms of two indexes for the public market valuations of publicly traded firms in the same industry as the firm at the beginning of the month of the financing (with January 1, 1987 normalized as 1.00 for each index), of the firm's age (in years) at the beginning of the year of the financing, and of the inflow into venture capital funds in the four quarters prior to the financing (in millions of 1995 dollars). In Panel B, the logarithm of the firm's sales (in millions of 1995 dollars) at the beginning of the year of the financing is an additional independent variable; in Panel C, the logarithm of the firm's employment at the beginning of the year of the financing is included. In the three panels, additional independent variables are added to the basic specification: the logarithm of a small capitalization stock index, the logarithm of the relevant price index twelve months prior to the investment, and a dummy variable denoting second and later rounds of venture capital investment. Only selected coefficients are presented. Absolute heteroskedastistic-consistent t-statistics in brackets.

Panel A: Adding a Small Capitalization Stock Index		
Log of Value-Weighted Industry Index	0.06 [1.20]	
Log of Equal-Weighted Industry Index		0.02 [0.39]
Log of Small Capitalization Stock Index	0.24 [2.77]	0.27 [2.42]
Log of Inflow of Venture Capital	0.14 [3.80]	0.14 [3.33]
Panel B: Adding a Lagged Price Index		
Log of Value-Weighted Industry Index	0.07 [0.80]	
Log of Equal-Weighted Industry Index		0.11 [1.36]
Log of Value-Weighted Industry Index from 12 Months Previously	0.23 [2.20]	
Log of Equal-Weighted Industry Index from 12 Months Previously		0.17 [2.00]
Log of Inflow of Venture Capital	0.14 [3.02]	0.13 [2.48]
Panel C: Adding a Dummy Variable for Later Venture Rounds		
Log of Value-Weighted Industry Index	0.27 [5.64]	
Log of Equal-Weighted Industry Index		0.30 [7.02]
Second or Later Venture Round?	0.47 [11.91]	0.46 [11.53]
Log of Inflow of Venture Capital	0.07 [1.74]	0.09 [2.05]

Table 9. Ordinary least squares (OLS) and Heckman sample selection regression analyses of changes in pre-money valuations between financing rounds. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round. The difference between the logarithm of the pre-money valuation in the subsequent and current venture rounds, expressed in millions of current dollars, is used as the dependent variable. The independent variables include dummy variables controlling for the firm's status, industry, and location at the time of the current round, dummies that indicate a change in status between the current and subsequent round, the logarithm of the time between the two financing rounds (expressed in years), and the differences in the logarithms of the two indexes of the valuations of publicly traded firms in the same industry as the firm (with January 1, 1987 normalized as 1.00 for each index) and of the inflows into venture capital funds in the four quarters prior to the financing (in millions of 1995 dollars). The third and fourth equations present the coefficients from the second equation in a two-equation system. (The initial equation controls for the probability that the current round is followed by another venture financing. The χ^2-statistic and the number of observations refer to the entire two-equation system.) Absolute heteroskedastistic-consistent t-statistics in brackets in the first two equations; absolute t-statistics in the third and fourth equations.

Independent Variables	*OLS Estimates*		*Heckman Equation Estimates*	
Stage of Firm in Prior Round:				
Firm is in Start-Up Stage?	0.84 [7.29]	0.84 [7.27]	0.81 [6.53]	0.80 [6.48]
Firm is in Development Stage?	0.58 [5.12]	0.57 [5.08]	0.55 [4.74]	0.54 [4.67]
Firm is in Beta Stage?	0.40 [2.98]	0.40 [2.96]	0.38 [3.00]	0.38 [2.97]
Firm is in Shipping Stage?	0.32 [2.85]	0.31 [2.81]	0.30 [2.80]	0.29 [2.74]
Firm is in Profitable Stage?	0.29 [2.42]	0.29 [2.38]	0.30 [2.37]	0.29 [2.33]
Firm is in Restart Stage?	0.80 [4.11]	0.79 [4.10]	0.79 [5.05]	0.78 [5.00]
Industry of Firm:				
Firm is in Data Processing Industry?	-0.05 [0.75]	-0.06 [0.78]	-0.05 [0.83]	-0.06 [0.88]
Firm is in Computer Software Industry?	-0.01 [0.19]	-0.01 [0.21]	-0.01 [0.22]	-0.01 [0.23]
Firm is in Communications Industry?	0.07 [1.15]	0.06 [1.09]	0.07 [1.24]	0.07 [1.17]
Firm is in Consumer Electronics Industry?	-0.03 [0.29]	-0.03 [0.32]	-0.03 [0.24]	-0.04 [0.26]
Firm is in Industrial Equipment Industry?	-0.20 [2.28]	-0.20 [2.29]	-0.20 [2.37]	-0.20 [2.38]
Firm is in Medical Industry?	0.01 [0.22]	0.01 [0.17]	0.01 [0.24]	0.01 [0.19]
Firm is in Instrumentation Industry?	-0.02 [0.19]	-0.02 [0.20]	-0.02 [0.19]	-0.03 [0.22]
Firm is in Components Industry?	-0.06 [0.68]	-0.06 [0.70]	-0.06 [0.58]	-0.06 [0.60]
Firm is in Semiconductor Industry?	0.06 [0.68]	0.06 [0.66]	0.06 [0.70]	0.05 [0.68]
Location of Firm:				
Firm is Based in Eastern States?	-0.01 [0.24]	-0.01 [0.24]	-0.02 [0.33]	-0.02 [0.33]
Firm is Based in Western States?	0.001 [0.02]	0.002 [0.04]	-0.01 [0.13]	-0.01 [0.13]
Events Between Prior and Current Round:				
Firm Began Active Product Marketing?	0.01 [0.26]	0.01 [0.25]	0.01 [0.26]	0.01 [0.24]
Firm Underwent Restart?	-1.72 [12.69]	-1.72 [12.71]	-1.72 [16.99]	-1.72 [17.00]
Log of Time Between Rounds	0.01 [0.27]	0.0003 [0.01]	0.001 [0.06]	-0.01 [0.21]
Change in Log of Value-Weighted Index	0.02 [0.27]		0.03 [0.44]	
Change in Log of Equal-Weighted Index		0.05 [0.75]		0.05 [1.01]
Change in Log of Venture Capital Inflow	0.08 [2.03]	0.08 [2.15]	0.08 [2.50]	0.09 [2.66]
Constant	0.13 [1.06]	0.13 [1.05]	0.19 [1.30]	0.20 [1.34]
R^2	0.23	0.23		
F-statistic	19.56	19.76		
χ^2-statistic			961.17	961.27
p-Value	0.000	0.000	0.000	0.000
Number of Observations	1941	1941	4064	4064

Table 10. Ordinary least squares regression analyses of pre-money valuations of financing rounds, dividing the sample by firm characteristics. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round. The logarithm of the pre-money valuation, expressed in millions of current dollars, is used as the dependent variable. In all regressions, the independent variables include dummy variables controlling for the firm's status, industry, and location, and the logarithms of two indexes for the public market valuations of publicly traded firms in the same industry as the firm at the beginning of the month of the financing (with January 1, 1987 normalized as 1.00 for each index), of the firm's age (in years) at the beginning of the year of the financing, and of the inflow into venture capital funds in the four quarters prior to the financing (in millions of 1995 dollars). In Panel B, the logarithm of the firm's sales (in millions of 1995 dollars) at the beginning of the year of the financing is an additional independent variable; in Panel C, the logarithm of the firm's employment at the beginning of the year of the financing. In Panel A, interactions between the market valuation, venture inflow, and firm characteristic variables are also used as independent variables (with a total of 3896 observations used in the regressions). Later-stage firms are defined as those in shipping or profitable stages at the time of the investment. In Panels B and C, the regression is restricted to firms in the eastern United States (a total of 641 observations) and in the later stages of investment (a total of 1579 observations). The relative impact of fundraising by venture funds located or specializing in that particular sector and other funds is compared. Absolute heteroskedastistic-consistent t-statistics in brackets.

Panel A: Adding Interaction Terms to the Base Regression		
Log of Value-Weighted Industry Index	0.19 [2.97]	
Log of Equal-Weighted Industry Index		0.21 [3.22]
Log of Inflow of Venture Capital	0.11 [2.29]	0.13 [2.71]
Log of Industry Index * Firm is in Later Stages?	0.02 [0.36]	-0.04 [0.68]
Log of Venture Inflow * Firm is in Later Stages?	0.09 [1.27]	0.07 [0.95]
Log of Industry Index * Firm is in California or Massachusetts?	-0.06 [0.87]	-0.06 [0.93]
Log of Venture Inflow * Firm is in California or Massachusetts?	0.02 [2.48]	0.02 [2.54]
Panel B: Exclusively Examining Firms Based in the Eastern United States		
Log of Value-Weighted Industry Index	0.16 [1.52]	
Log of Equal-Weighted Industry Index		0.19 [1.91]
Log of Inflow of Venture Funds Based in Eastern United States	0.38 [3.09]	0.41 [3.28]
Log of Inflow of Venture Funds Based Elsewhere in United States	-0.12 [0.98]	-0.13 [1.07]
p-Value, Test of Equality of Two Venture Inflow Variables	0.030	0.020
Panel C: Exclusively Examining Later-Stage Firms		
Log of Value-Weighted Industry Index	0.19 [3.05]	
Log of Equal-Weighted Industry Index		0.20 [3.53]
Log of Inflow of Venture Funds Focusing on Later-Stage Investments	0.11 [2.67]	0.10 [2.05]
Log of Inflow of Venture Funds Focusing on Other Investment Stages	0.08 [3.16]	0.09 [2.60]
p-Value, Test of Equality of Two Venture Inflow Variables	0.661	0.872

Table 11. Instrumental variable regression analyses of pre-money valuations of financing rounds. The sample consists of 4069 professional venture financings of privately held firms between January 1987 and December 1995 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The pre-money valuation is defined as the product of the price paid per share in the financing round and the shares outstanding prior to the financing round. The logarithm of the pre-money valuation, expressed in millions of current dollars, is used as the dependent variable. The independent variables include dummy variables controlling for the firm's status, industry, and location, and the logarithms of the firm's age (in years), of sales (in millions of 1995 dollars) and employment at the beginning of the year of the financing, of two indexes for the public market valuations of publicly traded firms in the same industry as the firm at the beginning of the month of the financing (with January 1, 1987 normalized as 1.00 for each index), and of the inflow into venture capital funds in the four quarters prior to the financing (in millions of 1995 dollars). The inflow into leveraged buyout funds in the four quarters prior to the financing (in millions of 1995 dollars) is used as an instrument for the inflow into venture funds. Absolute heteroskedastistic-consistent t-statistics in brackets.

Independent Variables	*No Firm Size Measure*		*Using Firm's Sales*		*Using Firm's Employment*	
Stage of Firm:						
Firm is in Start-Up Stage?	-0.85 [6.61]	-0.86 [6.72]	-0.88 [5.29]	-0.89 [5.37]	-0.76 [5.28]	-0.77 [5.40]
Firm is in Development Stage?	-0.13 [1.04]	-0.15 [1.19]	-0.07 [0.46]	-0.10 [0.60]	-0.01 [0.08]	-0.04 [0.32]
Firm is in Beta Stage?	0.14 [1.01]	0.11 [0.79]	0.23 [1.30]	0.19 [1.05]	0.25 [1.66]	0.19 [1.23]
Firm is in Shipping Stage?	0.17 [1.45]	0.16 [1.30]	0.19 [1.24]	0.16 [1.02]	0.20 [1.56]	0.15 [1.19]
Firm is in Profitable Stage?	0.53 [4.05]	0.51 [3.89]	0.47 [2.88]	0.42 [2.56]	0.47 [3.28]	0.40 [2.78]
Firm is in Restart Stage?	-1.21 [8.57]	-1.24 [8.74]	-1.28 [7.63]	-1.33 [7.92]	-1.26 [8.40]	-1.33 [8.91]
Industry of Firm:						
Firm is in Data Processing Industry?	0.32 [3.63]	0.26 [2.97]	0.27 [2.36]	0.17 [1.46]	0.35 [3.32]	0.24 [2.34]
Firm is in Computer Software Industry?	-0.04 [0.53]	-0.02 [0.27]	-0.09 [1.06]	-0.07 [0.81]	-0.05 [0.58]	-0.02 [0.20]
Firm is in Communications Industry?	0.34 [4.75]	0.29 [3.96]	0.28 [3.13]	0.19 [2.04]	0.34 [4.11]	0.23 [2.81]
Firm is in Consumer Electronics Industry?	0.25 [1.46]	0.25 [1.47]	0.27 [1.48]	0.26 [1.46]	0.23 [1.56]	0.22 [1.58]
Firm is in Industrial Equipment Industry?	-0.21 [2.04]	-0.24 [2.33]	-0.23 [1.76]	-0.29 [2.17]	-0.19 [1.54]	-0.24 [1.95]
Firm is in Medical Industry?	0.39 [5.86]	0.37 [5.37]	0.43 [4.89]	0.37 [4.03]	0.46 [5.91]	0.38 [4.68]
Firm is in Instrumentation Industry?	0.01 [0.13]	-0.02 [0.14]	0.04 [0.30]	-0.01 [0.10]	0.09 [0.73]	0.03 [0.27]
Firm is in Components Industry?	-0.04 [0.40]	-0.06 [0.51]	-0.06 [0.52]	-0.09 [0.69]	-0.07 [0.57]	-0.09 [0.68]
Firm is in Semiconductor Industry?	0.60 [5.54]	0.60 [5.47]	0.45 [3.73]	0.44 [3.57]	0.49 [4.55]	0.49 [4.46]
Location and Other Characteristics:						
Firm is Based in Eastern States?	0.10 [1.90]	0.09 [1.77]	0.17 [2.62]	0.15 [2.42]	0.16 [2.76]	0.15 [2.54]
Firm is Based in Western States?	0.30 [6.47]	0.29 [6.38]	0.33 [5.72]	0.33 [5.61]	0.32 [5.95]	0.31 [5.89]
Log of Firm Age (in years)	0.43 [13.91]	0.43 [13.90]	0.30 [7.17]	0.30 [7.10]	0.20 [4.64]	0.18 [4.35]
Log of Firm Sales			0.18 [7.39]	0.20 [7.65]		
Log of Firm Employment					0.27 [13.60]	0.29 [14.23]
Log of Value-Weighted Industry Index	0.16 [4.29]		0.27 [5.24]		0.31 [6.42]	
Log of Equal-Weighted Industry Index		0.15 [4.28]		0.27 [5.69]		0.35 [7.96]
Log of Inflow of Venture Capital	0.21 [5.60]	0.22 [5.85]	0.19 [3.87]	0.20 [4.17]	0.12 [2.67]	0.13 [2.81]
Constant	-0.47 [1.38]	-0.53 [1.53]	-0.42 [0.95]	-0.50 [1.12]	-0.52 [1.25]	-0.60 [1.44]
R^2	0.32	0.32	0.34	0.34	0.37	0.38
F-statistic	98.94	98.36	69.24	70.65	76.26	76.39
p-Value	0.000	0.000	0.000	0.000	0.000	0.000
Number of Observations	3896	3896	2433	2433	2622	2622

Table 12. Analyses of the success of venture backed firms. The sample consists of 1798 professional venture financings of privately held firms between January 1987 and December 1991 in the VentureOne database for which VentureOne was able to determine the valuation of the financing round. The first panel examines the percentage of the financings that were taken public (or had filed to go public) as of March 1996. The panel presents two divisions of observations: one comparing investments made in 1987 and 1988 with those made between 1989 and 1991, the other comparing those from 1987 through 1989 to those made in 1990 and 1991. The table also presents the average annual fund inflow in these periods (in millions of 1995 dollars), and the p-value from a χ^2-test of the equality of the probability of a successful outcome. The second panel examines the percent of investments that were taken public, had filed to go public, or had been acquired at more than twice the valuation of the original venture round.

Panel A: Successful Outcome is an Initial Public Offering (or IPO Filing)		
Year of Investment	*Average Fund Inflow in Period*	*Investments with Successful Outcomes*
1987-1988	4482	33.6%
1989-1991	2615	30.1%
p-Value, χ^2-Test of Equality of Success Probabilities		0.141
Year of Investment	*Average Fund Inflow in Period*	*Investments with Successful Outcomes*
1987-1989	4348	32.5%
1990-1991	1881	29.7%
p-Value, χ^2-Test of Equality of Success Probabilities		0.209
Panel B: Successful Outcome is an IPO (or IPO Filing) or Acquisition at 2 or More Times Original Valuation		
Year of Investment	*Average Fund Inflow in Period*	*Investments with Successful Outcomes*
1987-1988	4482	35.5%
1989-1991	2615	31.7%
p-Value, t-Test of Equality of Success Probabilities		0.106
Year of Investment	*Average Fund Inflow in Period*	*Investments with Successful Outcomes*
1987-1989	4348	34.5%
1990-1991	1881	31.1%
p-Value, t-Test of Equality of Success Probabilities		0.115

Chapter 5

Recommendations

The Advanced Technology Program (ATP) is a public initiative to support research with significant technological and commercial potential in partnership with large and small firms. In this report, we examine the financial environment in which small, technology-intensive firms operate and draw implications for the ATP.

Through both large-sample research and case studies, we explore (1) how venture capital organizations do and do not address the needs of small high-technology firms and (2) the interactions between venture financing and public initiatives to assist these firms. As part of the second analysis, we examine the ways in which the Advanced Technology Program can further its mission of "stimulat[ing] U.S. economic growth by developing high risk and enabling technologies." We highlight five key recommendations:

- The Advanced Technology Program should continue to invest in building relationships with, and developing an understanding of, the U.S. venture capital industry. Financing small entrepreneurial firms is exceedingly challenging. The venture capital industry employs a variety of important mechanisms to address these challenges. Empirical evidence suggests that these tools are quite effective. Because of the magnitude and success of venture capital financing, it is important that administrators of the Advanced Technology Program view their actions in the context of this financial institution.

- The Program's investment choices should be made with an eye to the narrow technological focus and uneven levels of venture capital investments. Venture investments tend to be focused on a few areas of technology that are perceived to have particularly great potential. Increases in venture fundraising—which are driven by factors largely exogenous to the venture capital industry (e.g., shifts in capital gains tax rates)—appear more likely to lead to more intense price competition for transactions within an existing set of technologies than to greater diversity in the types of companies funded. The ebbs and flows of venture capital fundraising are often difficult to predict. Program administrators may wish to respond to these conditions by (1) focusing on technologies that are not currently popular among venture investors and (2) providing follow-on capital to firms already funded by venture capitalists during periods when venture inflows are falling.

- The Program administrators must appreciate the need for flexibility that is central to the venture capital investment process. Venture capitalists make investments into young firms in settings with tremendous technological, product market, and management uncertainties. Rather than undertaking the often- impossible task of addressing all the uncertainties in advance, they remain actively involved after the investment, using their contractually specified control rights to guide the firm in response to changing conditions. These changes—which often involve shifts in product market strategy and the management team—are an integral part of the investment process. Advanced Technology Program administrators too often appear to view these shifts as troubling indications that awardees are deviating from plan, rather than as a natural part of the evolution of new ventures.

- *Advanced Technology Program administrators should examine the track record of the firms receiving the awards.* While many firms were very seriously oriented to the commercial

marketplace, in some instances it appeared that the Advanced Technology Program awardees had a "contract research" mentality. In extreme cases, they had already received awards from a variety of federal technology programs, such as the Small Business Innovation Research program and the Department of Defense's Advanced Research Projects Agency, without having generated any commercial outcomes. These firms are unlikely to be able to effectively commercialize new technologies. A careful examination of applicants' past experience with Federal technology programs and their track record in commercializing these projects should be an important evaluation criterion. We would recommend erring on the side of making awards to entrepreneurial firms that have not received previous federal funding.

- Program administrators must think carefully about the validity of the concept of "pre-commercial research" in an entrepreneurial setting. An extensive body of entrepreneurship research has demonstrated the unpredictability of the entrepreneurial process. Very few entrepreneurs, whether in high- or low-technology settings, commercialize what they initially set to develop in their original time-frame. Rather, successful entrepreneurs gather signals from the marketplace in response to their initial efforts and adjust their plans accordingly. Once they identify an opportunity, they move very rapidly to take advantage of it before major corporations can respond. Consequently, to push entrepreneurs to devote Advanced Technology Program funds to purely pre-commercial research may cause them to ignore an essential source of information: i.e., feedback from customers. Even more detrimental have been instances where companies—having identified an attractive commercial opportunity—are afraid to rapidly pursue it, lest they jeopardize their public funds (on which they are relying as a key source of financing) on the grounds that they are pursuing commercial research. While well intentioned, such policies may have the perverse effect of punishing success and encouraging counter-productive strategies. One potential change would be to allow firms that rapidly commercialize publicly funded projects to use their Program funds to pursue another project.

Appendix: ATP Comments on Authors' Recommendations

Of the five recommendations, the ATP agrees in principle with three, but also takes issue with at least portions of four of the recommendations. Since ATP administrators were not interviewed concerning facts or interpretations relating to the authors' recommendations, the ATP response to the authors is provided here.

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The ATP agrees with the authors' first recommendation—that the ATP should continue to invest in building relationships with, and developing an understanding of, the U.S. venture capital industry. In fact, ATP's commissioning of this study was done in accordance with this point of view.

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The ATP does not agree with the authors' second recommendation—that the ATP should avoid investing in technology focus areas that are currently receiving venture capital funding, and should aim to provide follow-on capital to venture-backed firms during times when venture inflows are falling. This recommendation misses the enabling technology focus of the ATP. All projects within a broad technology area are not the same. Some will be readily funded by private investment funds; others will not. In ATP's view, technology projects with great social benefit potential, that either will not be developed or will proceed too slowly without the ATP, can be found in a wide variety of technological areas. And furthermore, such projects can coexist in companies side-by-side with projects that will be adequately funded by the private sector alone. The ATP therefore seeks to fund research across the full spectrum of technological areas, including the life sciences, chemistry and materials, electronics and photonics, manufacturing processes, information technology, and others, in order to develop enabling technologies in all areas. The ATP believes that it should continue to look for opportunities where they arise, rather than close the door to certain technological areas because of the general presence of venture capital funding. For the same reason, ATP rejects the recommendation that it direct its funding to companies simply because they are losing venture funding. ATP's funding decisions depend both on "what" is to be funded, as well as on whether alternative funding is available from other sources.

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While the ATP agrees with the authors' third recommendation—that ATP administrators must appreciate the need for flexibility—it takes issue with the authors' related conclusion that ATP administrators view project change negatively. ATP management recognizes that unexpected technical bottlenecks, organizational changes, and market shifts often affect projects during the time the project is underway. In such cases, ATP project managers are prepared to accept appropriate adjustments to project plans, and in actual practice they often have. Professors Gompers and Lerner chose not to interview ATP managers about project situations that warranted adjustment to plans. Had they done so, they would have had opportunity to learn about the differences between allowable and non-allowable changes to plan.

Like other government agencies, ATP has a responsibility to ensure that the public funding that companies receive are used for the purposes designated by the award. ATP cannot allow a company to transfer government funds from legislatively approved uses to uses that are not approved and which the auditors will disallow. Neither can ATP allow a company to drop critical aspects of the ATP funded research in order to do lower-risk research that the firm may prefer to do, but which it could pursue on its own with private sources of funding. ATP funding is based
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on a cost-sharing cooperative agreement with industry participants, which carries mutually agreed upon terms and conditions. If ATP officials in a specific case believe that proposed changes will reduce significantly the spillover benefits potential of a project, they may not be flexible on allowing such changes. In some situations, ATP managers may have to balance concerns about adverse impact on potential spillovers if project changes are made with concerns about adverse impacts on the innovating company's business performance if the changes are not made.

In general, the major flaw in the authors' approach is that they make over-reaching generalizations based on very limited information. They have a sample of seven firms out of a population that includes more than 1,000 companies. It is ATP's position that the authors' simply had inadequate information to generalize as broadly as they did about the motives of ATP administrators. Perhaps administrators are too flexible; perhaps they are too inflexible; perhaps they have about the right degree of flexibility. The operational question on flexibility is not uninteresting; it is simply not answered by this study. The correct representation of what the authors actually found is that at least one of the seven company representatives wanted more flexibility to make changes than was allowed by ATP officials. That is all that can be concluded.

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The ATP agrees with the authors' fourth recommendation—that program administrators should examine the track record of firms receiving the awards. This is done now, but there is always room for improvement within the program's constraints of time, budget, and staff. We do not agree, however, with the authors' related recommendation that we should favor entrepreneurial firms that have not received previous Federal funding. We find this to be an oversimplification. The ATP requires a listing of previous Federal funding of a company prior to a funding decision. It investigates whether the work is already receiving Federal support; and maintains close contacts with other Federal agencies to guard against funding overlaps. The ATP looks for indications that an applicant is operating as a "contract research mill" with little commercial follow-through, e.g., receiving multiple SBIR Phase I grants with no further development. The ATP avoids funding projects proposed by such companies unless they are partnered with strong market-oriented companies. The ATP, however, does not view prior receipt of SBIR grants as negative *per se*, nor receipt of NSF, DARPA, NIH, or other government grants *per se*. Often, precursor research of a more basic nature has been carried out in a university or elsewhere under a government research grant prior to reaching the more applied stage appropriate for ATP funding. Often, small companies use a series of SBIR Phase I, Phase II, and Phase III grants to get started, before being in position to take on a larger effort that can be backed by ATP.

The ATP deliberately takes an aggressive stance in funding small start-up and near start-up companies that are proposers of radical new technologies. The NIST "Visiting Committee," an external advisory board to NIST, was recently briefed about the higher failure rate of very small companies in ATP's portfolio of completed projects. The Committee concluded that the failure rate was within an acceptable range given the technology benefits of encouraging participation in the program by small, highly innovative companies. At the same time, the ATP aims to carry out due diligence in examining applicants' track records.

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The ATP disagrees with the authors' fifth recommendation—that the ATP should permit firms that rapidly commercialize their publicly funded projects to use any residual funds to pursue another project. Again, this misses several points about the ATP: (1) the ATP is not simply a funding source to replace venture funding when it dries up; rather the ATP funds enabling

technologies which firms are not likely to pursue in a timely way without the ATP; and (2) there are legal restrictions on what ATP funding can and cannot be used to support. The program was created by Congress to fund innovative technology in the "pre-commercial" stage; there would surely be a danger of displacing private capital if, as the authors recommend, the ATP were to allow companies to use the funds in any way they chose. Moreover, since the ATP is a cost-sharing program, the concept of residual funds really does not apply because if costs are not incurred by companies in their ATP projects, then ATP's cost-share is also zero. There is no residual. The authors have identified an issue that the companies and the authors apparently believe deserves more attention. That is, are companies that accomplish their research goals faster (cheaper) than originally expected unfairly treated, or given disincentives to commercialize, by ATP's cost-share rules which permit the ATP to cover only its specified share of actual project R&D costs? Is it the "right" of the companies to receive the originally announced award amount to do with as they please, or should they use it only for the agreed-on research project specified in the terms and conditions of the award? As a custodian of public funds, the ATP's position is that it is the latter.

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In summary, our criticisms of the study center on the tendency to over generalize in making recommendations for the operations of the program. The authors make judgments based solely on the perspective of company representatives, while ignoring the objectives, perspective, and legal basis of the ATP. In total, there are seven companies in the case study sample of firms. And many times the authors' conclusions appear to derive from the experience or views of just one or two companies. The authors did not interview ATP administrators, and so their conclusions and recommendations seem in many cases to be incomplete or lacking in information.

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